P. S. Samson

From Prof. Armstrong

Oct, 1910

(Reproduced)

TECHNICAL DRAWING SERIES

ANTHONY'S MECHANICAL DRAWING

ANTHONY'S MACHINE DRAWING

ANTHONY'S GEARING

ANTHONY AND ASHLEY'S DESCRIPTIVE GEOMETRY

DANIELS'S FREEHAND LETTERING

DANIELS'S TOPOGRAPHICAL DRAWING

D. C. HEATH & CO., PUBLISHERS

MACHINE DRAWING

THE PRINCIPLES OF GRAPHIC EXPRESSION AS ILLUSTRATED BY MACHINE DRAWING, TOGETHER WITH THE TECHNIQUE OF DRAFTING, DIMENSIONING, AND SKETCHING

BY

GARDNER C. ANTHONY, A.M., Sc.D.

PROFESSOR OF DRAWING IN TUFTS COLLEGE AND DEAN OF THE ENGINEERING SCHOOL
AUTHOR OF "ELEMENTS OF MECHANICAL DRAWING," "ESSENTIALS OF GEARING," AND "DESCRIPTIVE
GEOMETRY"; MEMBER OF THE AMERICAN SOCIETY FOR THE PROMOTION OF ENGINEERING EDU-
CATION; MEMBER OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

PREFACE

IT is with some degree of hesitancy that the author republishes this book under the old title, since it is misleading, as indeed are most of the titles used for books dealing with graphic language. There is no more unfortunate term than that of "mechanical drawing" as applied to the elementary course in graphic language, but usage compels its continuance for the present. It is true that this treatise deals chiefly with the drawings of machine parts, but only because they give a greater scope for varied expression and a better study of the technique of graphics, than do architectural, topographic, or structural subjects.

It has been the aim of the author to teach and encourage the use of concise graphic terms by adopting the idiomatic phrases of the engineer, and to suggest many useful means for acquiring facility in this form of expression. To attain this end, numerous examples have been chosen from practice with a view to obtaining the largest experience consistent with a minimum expenditure of time. These problems have received the severe test of use in the classes of high schools, manual training schools, and technical colleges.

Most of the old illustrations have been redrawn; all have been newly engraved and new examples have been added.

The author desires to express his thanks for the helpful criticisms which have come from many who have found the old editions useful in the classroom, and especially to his associate in teaching, Mr. Carl L. Svensen, who has contributed many valuable suggestions to this revision.

TUFTS COLLEGE,
July, 1910.

GARDNER C. ANTHONY.

TABLE OF CONTENTS

CHAPTER III

GENERAL RULES FOR MAKING DRAWINGS

CHAPTER IV

SECTIONAL VIEWS

CHAPTER V

DIMENSIONING

CHAPTER VI

TECHNICAL SKETCHING

CHAPTER VII

EXAMPLES FOR PRACTICE

TABLES

MACHINE DRAWING

INTRODUCTION

1. This book is designed to teach exact methods of thought and clear expression in graphic language. The examples chosen are those commonly used in practice and should therefore quicken the interest in, and give a greater appreciation of, the one universal language. Although the title suggests a somewhat limited sphere it should be clearly understood that the best training in graphic language comes through the reading and making of machine drawings together with the sketching of machine parts. This is due to the great variety and complexity of modern machinery which requires an exact, as well as

concise, expression of one's ideas, and a greater vocabulary, or knowledge of the many conventions which go to make up a graphic language.

An engineer may have a good knowledge of projection, the ability to draw the most complicated device, to make the several sections for illustrating the inner parts, and yet fail to express his ideas in an intelligible manner. Such failures are largely due to an ignorance of the idioms of the language and insufficient knowledge of the requirements of the artisan to whom this graphic letter is addressed. An understanding of the former may be gained through the study of this branch of graphics,

1

but the latter must be obtained largely through experience. Nevertheless, many things may be learned by the study and practice of such exercises as are herein presented.

A proper study of machine drawing cannot be made without giving some consideration to machine design, as is suggested by the contents of the following chapters; but this is treated as secondary to the development of the art of acquiring a concise and clear graphic expression. With this end in view the problems may be studied in any order that the wisdom of the instructor may suggest, and the requirements varied to suit the needs of the individual.

It is intended that the student shall begin at once with the solution of problems, since a knowledge of the use of instruments, projection, and other essentials of elementary graphics is presupposed; but all of the references to the subject-matter of this treatise must be mastered and carefully observed when solving the problems.

It is not usual for students to arrive at this stage of the course with a sufficiently accurate working knowledge of bolts and screws, and since these elements are essential to all machine construction they should be so thoroughly understood as to cause no hesitancy in illustrating them. To this end chapters 1 and 2 should be studied at the beginning of a course, and the following chapters considered as the requirements of the course may suggest.

The tables of various standards have been introduced for the purpose of familiarizing the student with the actual requirements of practice as well as to initiate him into some of the essentials of machine design.

CHAPTER 1

SCREW THREADS

2. **The representation of bolts, nuts, screws, and screw threads** is of such importance that a thorough knowledge of their proportions and the conventional method of illustrating them is of the first consideration to the draftsman. Printed tables of the dimensions of bolt-heads, nuts, set screws, etc., are usually published in treatises on machine design, but it is far better for the student to fix the proportion of the various parts in his mind, and learn to judge for himself of the comparative value of types and conventions. The present treatise illustrates the more common types only, and it is assumed that the student is already familiar with the theory of the helix and its application to the various forms of screw threads, as well as the drawing of a hexagonal bolt-head and nut.* In the study of the following pages the student is recommended to master each type in order that he may rapidly draw, or sketch, the bolt or screw with its proper proportions, but without the aid of the illustrations, and having only the diameter of the threads given.

* For a complete treatise on the helix and its application to the drawing of screw threads, together with the construction of the hexagonal bolt-head and nut, see " Elements of Mechanical Drawing," of this series.

3. U. S. Standard and V Screw Threads. The
form of thread commonly used is that known
as the Sellers, or U. S. Standard, and shown
by Fig. 1. This differs from the sharp V
thread of Fig. 2 by the flattening of the
thread at the top and bottom. The propor-
tions of these threads are given in the illustra-
tions, and the formulas for obtaining the U. S.
Standard proportions are as follows: $D =$
outside diameter. $P =$ pitch. $N =$ number of
threads per linear inch.

$$P = \frac{1}{N} = 0.24 \sqrt{D + 0.625} - 0.175.$$

$$S = 0.65\,P = \frac{0.65}{N}.$$

Although the pitch in single-threaded screws
is, properly speaking, the distance between con-
secutive threads, the term is often applied to
designate the number of threads per inch.
Thus a screw having eight threads per inch is
spoken of as eight pitch.

The standard number of threads per inch
for diameters from $\frac{1}{4}''$ to $2\frac{1}{2}''$ are given in
the table on page 11.

U. S. STANDARD V THREAD
Fig. 1.

Fig. 2. SHARP V THREAD

Fig. 3. WHITWORTH THREAD

Fig. 4. SQUARE THREAD
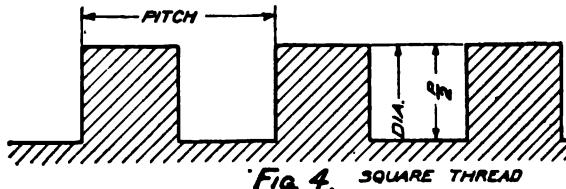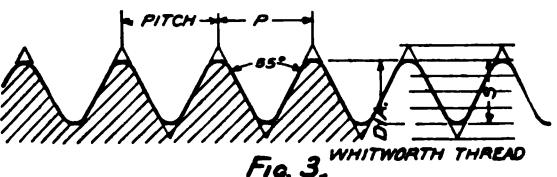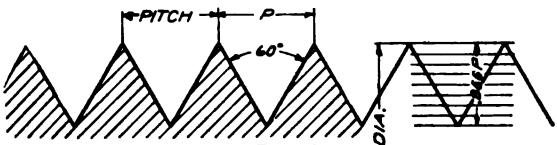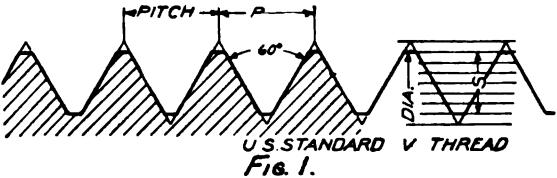
4. **Whitworth's Thread.** The standard British thread is illustrated by Fig. 3. This differs from the U. S. Standard in being rounded at top and bottom, and having an angle of 55° instead of 60°. The proportions
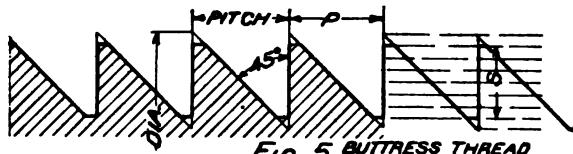
FIG. 5. BUTTRESS THREAD
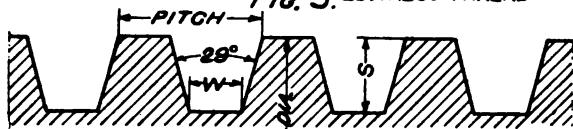
FIG. 6. ACME THREAD

are given by the following equations, the notation being the same as in Art. 3.

$$P = \frac{1}{N} = .08\,D + 0.04, \text{ nearly.} \quad S = .64\,P.$$

The standard number of threads per inch is the same as for the U. S. Standard given on page 11, save in the case of the $2\frac{1}{4}''$ screw which has 4 instead of $4\frac{1}{2}$ threads per inch.

5. **Square Thread.** This thread has the advantage of receiving the thrust parallel to the axis, and operates with less friction than the V type, but it is expensive to fit. It is largely used for power transmission. The proportions are shown by Fig. 4, the pitch for standard threads being twice that for V threads.

6. **Buttress Thread.** Fig. 5 illustrates a third type which is sometimes known as a ratchet thread. It is used for imparting motion where the strain is in one direction only, as a screw jack. By this means the friction is reduced while the strength of the V thread is maintained. The proportions are those given in the figure.

7. **Acme Thread.** Fig. 6. This is used in machine tools where a disengaging nut is required. The angle between the threads is 29°, being the same as that generally adopted for worm gearing. The proportions are as follows :

$$S = 0.5\,P + 0.02. \quad W = \frac{0.3707}{N} - 0.0052.$$

This is also known as the Powell thread.

8. Representation of V Threads. Figs. 7 and 8 represent a right and a left-hand single V thread, and Fig. 12 a double V thread. This method of representation is seldom used because of the labor of drawing the V. The best conventional method of drawing the thread is shown by Figs. 9 and 10, the former of which is preferable. The objection to the latter is in the greater length of the heavy lines which obscures more of the drawing, thus leaving too little space for dimensions. It is rarely necessary to draw the standard number of threads per inch as given in the table, the representation being clearer when a smaller number is used, and the drawing of unnecessary lines is thus saved. If it is of importance to specify the pitch it is best done by Roman numerals, indicating the number per inch as in Fig. 9. A double thread is shown in Fig. 11 for the purpose of drawing attention to the difference between it and the single thread. Its character is better illustrated by Fig. 12.

In the case of a dotted thread, economy in the use of lines is of still greater importance,

Right hand Single V Thread   Left hand Single V Thread

FIG. 7.   ‑P‑   ‑P‑ FIG. 8.

Single V Thread   Single V Thread

FIG. 9.   FIG. 10.   ‑P‑

Double V Thread.   Double V Thread.

FIG. 11.   FIG. 12.

Single Square Thread   Double Square Thread
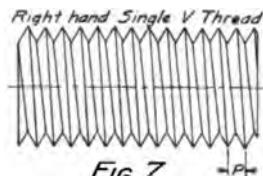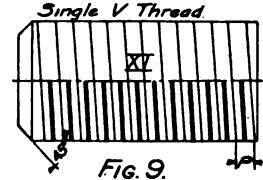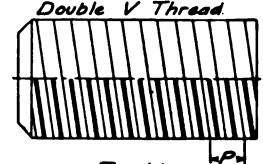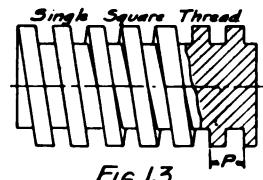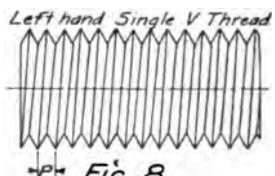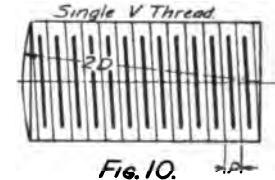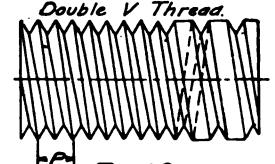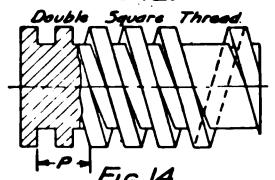
FIG. 13.   FIG. 14.

and the V alone is often used as illustrated by Fig. 22, page 9 .

9. Since it is necessary to remove the sharp feather edge at the end of a thread, the end of the screw must be chamfered as in Fig. 9 or rounded as in Fig. 10. When the latter form is used the length of the screw or thread is measured from the intersection of the rounded end and cylinder.

10. Representation of Square Threads. Fig. 13 illustrates a section and two conventional forms of the square thread. That on the left is the more simple form, and the one commonly used ; but the other representation is the more correct, in that the inner helix has been shown. In representing this type of screw it is usually better to draw the exact number of threads per inch unless the scale is small, or the pitch very fine.

Fig. 14 illustrates a double square thread which differs from the single in having the square sections of the thread exactly opposite each other.

11. Taps. The tap is a hardened and tem- pered steel screw having cutting edges formed by three or four longitudinal slots which serve to transform the section of the thread thus

Fig. 15.

Taper Tap.
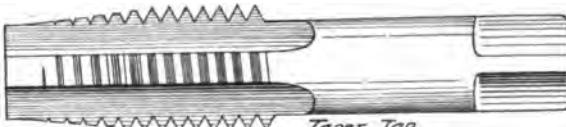
Fig. 16.
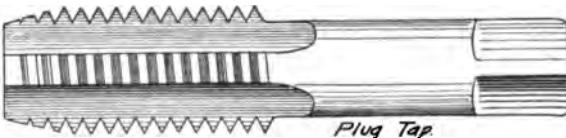
Plug Tap.
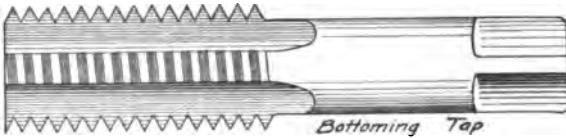
Fig. 17.

Bottoming Tap

made into a cutting edge. Three types of taps are supplied to the trade and are known as taper tap (Fig. 15), plug tap (Fig. 16), and bottoming tap (Fig. 17).

12. **The taper tap** is used for all holes in which it is possible to screw the tap completely through the hole.

13. **The plug tap** is used for threading a hole which is not drilled completely through the metal. This type is tapered for a short distance only, as indicated in the figure, but allowance must be made for the incomplete thread at the bottom of the hole.

14. **The bottoming tap** is employed only when it is necessary to have the full size of the thread continued to the very bottom of the hole which does not pass completely through the metal. This type is seldom used, inasmuch as it is generally possible to make the tapped hole of sufficient depth to not require the whole of it for the bolt or stud. If a bottoming tap is used, the thread must first be started by a plug tap and then followed by the bottoming tap.

15. **To determine the length of the threaded portion of tapped holes and screws** it will be necessary to observe the following: When tapping a screw into a like metal the length of the thread on the screw may be equal to the thickness of the nut, which is equal to the diameter of the bolt. But if tapped into a weaker metal it will be necessary to increase this length of thread. In general, it is well to add 50 %, which would be a safe margin for the tapping of a steel bolt in to cast iron, and will allow for the chamfering of the ends. Again, it must be observed that when the hole cannot be drilled through the material, as in Fig. 23, the tapped portion must extend beyond the end of the screw an amount varying from $\frac{1}{4}$ to $\frac{1}{2}$ an inch, depending upon the size and character of the thread desired. A good rule for general use in threading screws and tapping holes is as follows: Length of thread $1\frac{1}{2}$ times diameter of bolt. Length of tapped hole $1\frac{3}{4}$ times diameter of bolt. In the case of a stud, Fig. 24, it is often desirable to have the thread jammed at the bottom of the hole so as to prevent turning. Or the stud may be threaded to such length that it will jam at the top end of the thread. In either case the jamming of the thread will serve to prevent the turning of the stud when starting the nut.

Tapped holes.

FIG. 18.

FIG. 19.

FIG. 20.

FIG. 21.

Tap Bolt.
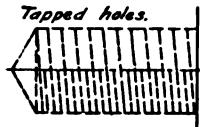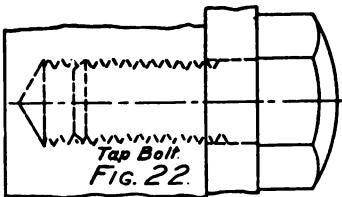
FIG. 22.
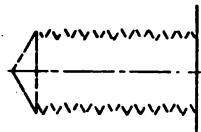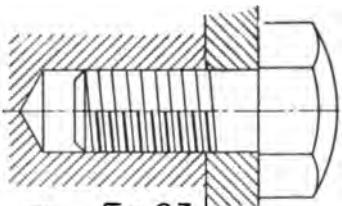
FIG. 23.
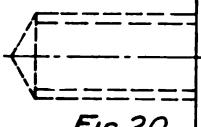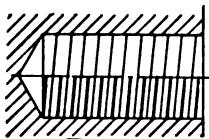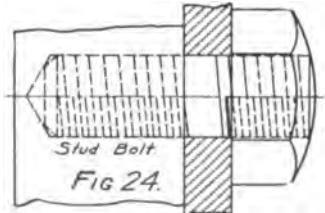
Stud Bolt.

FIG. 24.

16. The representation of tapped holes. When a tapped holes is dotted it may be shown as in Figs. 18, 19, or 20. If the drawing is already crowded with lines, the conventional representation of Fig. 18 would be objectionable, and that of Fig. 19, or Fig 20, should be used. The V's of the former may be drawn free hand, but care should be used to prevent a ragged appearance.

Fig. 21 illustrates a tapped hole in section, and as these illustrations are for right-hand threads only, the threads in this case will be inclined in an opposite direction to those of Fig. 23.

The end view of a tapped hole is frequently shown by two concentric circles, Fig. 20, the outer of which is made equal in diameter to that of the thread.

When a tapped hole is extended beyond the end of the screw as illustrated in Fig. 23 it is better to omit the threads in this portion unless the conventional representation of Fig. 22 be used. This is done to clearly define the end of the screw.

17. Table for the U. S. Standard V thread, and the sharp V thread.

Column 1, the outside diameter of the thread.

Column 2, the number of threads per inch, the pitch being the reciprocal of this number.

Column 3, the diameter of the root or bottom of thread.

Column 4, the diameter of drill to be used. It will be observed that the sizes are a trifle larger than the diameters at root of thread. The increase should be from about .004 of an inch for a $\frac{1}{4}$-inch tap to .01 for a 2-inch tap.

Columns 5, 6, 7, and 8 are of especial value to the machine designer and are introduced here to enable the student to obtain some appreciation of the strength of the thread. The weakest part being at the root, its strength will be dependent upon the diameter of this part and the tensile strength of the material. In the case of a screw of $1\frac{1}{4}$ inch diameter the dimension at the root is found in column 3 to be 1.065, the area of which is .78. If it is required that 4000 lbs. be the strain to which every square inch is subjected, then will the thread sustain .78 times 4000 lbs., which is

3120, as given in column 5. In this manner the table is constructed for four, five, six, and seven thousand pounds tensile strength.

18. A valuable application of this table is in determining the size of a screw, having given the total load to be sustained and the permissible strength per square inch. Thus if it is required to determine the diameter of a bolt sufficient to overcome a resistance of 10,000 lbs. and to be strained to only 4000 lbs. per square inch, proceed as follows: In column 5 find the number nearest to the required amount, in this case 9200. Against this number in column 1 is seen 2, which is the necessary diameter of the screw. If, however, the allowable strain per square inch had been 7000 lbs., a screw of $1\frac{5}{8}$ inch diameter could have been used.

19. Columns 9, 10, 11, 12 give values for the sharp V thread, used for rough iron sizes, corresponding to those of the U. S. Standard in columns 1 to 4. It will be observed that the outside diameters in column 9 are from $\frac{1}{64}$ to $\frac{1}{32}$ of an inch larger than those in column 1, this being the amount due to the flattening of the U. S. Standard thread.

PROPORTIONS FOR U. S. STANDARD AND V. THREADS.

U. S. STANDARD THREAD.				STRENGTH OF U. S. STAND. THREAD.				THREAD FOR ROUGH IRON SIZES.			
Diameter of Screw.	Threads per Inch.	Diameter at root of Thread.	Diameter of Tap Drill.	Tensile Strength at 4000 lbs. per Sq. Inch.	Tensile Strength at 5000 lbs. per Sq. Inch.	Tensile Strength at 6000 lbs. per Sq. Inch.	Tensile Strength at 7000 lbs. per Sq. Inch.	Diameter of Screw.	Threads per Inch.	Diameter at root of Thread.	Diameter of Tap Drill.
1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**
$\frac{1}{4}$	20	.185	$\frac{3}{16}$	107	134	161	187	$\frac{1}{4} + \frac{1}{64}$	20	.179	$\frac{7}{32}$
$\frac{5}{16}$	18	.240	$\frac{1}{4}$	181	226	271	316	$\frac{5}{16} + \frac{1}{64}$	18	.232	$\frac{17}{64}$
$\frac{3}{8}$	16	.294	$\frac{5}{16}$	271	339	407	475	$\frac{3}{8} + \frac{1}{64}$	16	.282	$\frac{5}{16}$
$\frac{7}{16}$	14	.344	$\frac{23}{64}$	371	465	558	650	$\frac{7}{16} + \frac{1}{64}$	14	.329	$\frac{3}{8}$
$\frac{1}{2}$	13	.400	$\frac{13}{32}$	500	625	750	875	$\frac{1}{2} + \frac{1}{64}$	13	.382	$\frac{7}{16}$
$\frac{9}{16}$	12	.454	$\frac{15}{32}$	647	809	971	1133	$\frac{9}{16} + \frac{1}{64}$	12	.434	$\frac{1}{2}$
$\frac{5}{8}$	11	.507	$\frac{17}{32}$	807	1009	1211	1413	$\frac{5}{8} + \frac{1}{64}$	11	.483	$\frac{17}{32}$
$1\frac{1}{8}$	11	.569	$\frac{37}{64}$	1017	1271	1525	1780	$1\frac{1}{8} + \frac{1}{32}$	11	.561	$\frac{37}{64}$
$\frac{3}{4}$	10	.620	$\frac{5}{8}$	1200	1500	1800	2100	$\frac{3}{4} + \frac{1}{32}$	10	.608	$\frac{21}{32}$
$1\frac{1}{8}$	10	.674	$1\frac{1}{16}$	1430	1780	2140	2500	$1\frac{3}{8} + \frac{1}{32}$	10	.671	$\frac{23}{32}$
$\frac{7}{8}$	9	.731	$\frac{3}{4}$	1680	2100	2520	2940	$\frac{7}{8} + \frac{1}{32}$	9	.714	$\frac{25}{32}$
$1\frac{5}{16}$	9	.793	$1\frac{3}{16}$	1980	2470	2960	3460	$1\frac{5}{16} + \frac{1}{32}$	9	.776	$\frac{27}{32}$
1	8	.837	$2\frac{7}{32}$	2200	2750	3300	3850	$1 + \frac{1}{32}$	8	.815	$\frac{7}{8}$
$1\frac{1}{8}$	7	.940	$3\frac{1}{32}$	2770	3460	4160	4850	$1\frac{1}{8} + \frac{1}{32}$	7	.909	$\frac{31}{32}$
$1\frac{1}{4}$	7	1.065	$1\frac{3}{32}$	3120	3900	4680	5460	$1\frac{1}{4} + \frac{1}{32}$	7	1.034	$1\frac{3}{32}$
$1\frac{3}{8}$	6	1.160	$1\frac{3}{16}$	4240	5300	6360	7420	$1\frac{3}{8} + \frac{1}{32}$	6	1.117	$1\frac{3}{16}$
$1\frac{1}{2}$	6	1.284	$1\frac{9}{32}$	5120	6400	7680	8960	$1\frac{1}{2} + \frac{1}{32}$	6	1.243	$1\frac{5}{16}$
$1\frac{5}{8}$	$5\frac{1}{2}$	1.389	$1\frac{13}{32}$	6120	7650	9180	10710	$1\frac{5}{8} + \frac{1}{32}$	$5\frac{1}{2}$	1.341	$1\frac{13}{32}$
$1\frac{3}{4}$	5	1.491	$1\frac{1}{2}$	7040	8800	10560	12320	$1\frac{3}{4} + \frac{1}{32}$	5	1.435	$1\frac{1}{2}$
$1\frac{7}{8}$	5	1.616	$1\frac{5}{8}$	8120	10150	12180	14210	$1\frac{7}{8} + \frac{1}{32}$	5	1.560	$1\frac{5}{8}$
2	$4\frac{1}{2}$	1.712	$1\frac{3}{4}$	9200	11500	13800	16100	$2 + \frac{1}{32}$	$4\frac{1}{2}$	1.646	$1\frac{23}{32}$
$2\frac{1}{4}$	$4\frac{1}{2}$	1.962	2	12480	15600	18720	21840	$2\frac{1}{4} + \frac{1}{32}$	$4\frac{1}{2}$	1.896	$1\frac{31}{32}$
$2\frac{1}{2}$	4	2.176	$2\frac{3}{16}$	14800	18500	22200	25900	$2\frac{1}{2} + \frac{1}{32}$	4	2.098	$2\frac{3}{16}$

CHAPTER 2

BOLTS AND SCREWS

20. Bolts and Screws. Save for the hexagonal bolt-head and nut, there is no generally accepted standard for the heads of bolts and screws. It is essential, however, for the draftsman to employ some system in the illustration of forms which occur so frequently as these do. The time required to properly design the head of a bolt, set screw, or other fastening device, is very considerable, and to have done it once should suffice. When a definite form of head is required, it should only be necessary to produce the same according to certain proportions already fixed, and obtainable either from a ready reference table or, better still, from memory. As it is generally unnecessary to give all the dimensions of the head or nut on the drawing, it is immaterial whether the representation conforms exactly to the finished size or not. It is therefore a useless delay for the draftsman to spend any more than time enough to produce the desired type of head according to his standard. The following proportions are suggested from standards already in use by many shops, and the proportions for the types commonly used should be committed to memory.

21. U. S. Standard Hexagonal Head and Nut. Two types of head and nut are illustrated, the rounded or spherical, Fig. 25, and the chamfered or conical, Fig. 26. In general the chamfered head is used for sketching, for

Fig. 25.
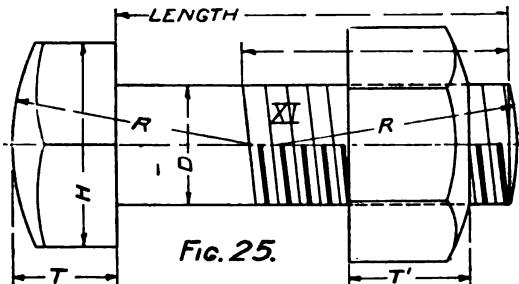
D = DIAMETER OF BOLT
H = 1½ D + ⅛˝
T = ½
T' = D
R = 2D OR 2½ D

Fig.26.
LENGTH.
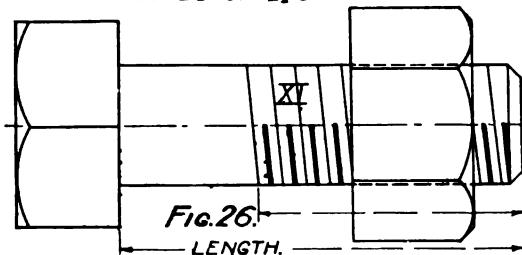
rough work, and whenever a special finish is not required. The rounded head, which presents a more finished appearance, is used almost exclusively for the heads and nuts of bolts of finished machinery. Three dimensions are fixed by the Government standard ; first, the distance across flats, or short diameter, commonly marked H, and equal to one and one half times the diameter of the bolt, plus one eighth of an inch. Second, the thickness of the head, equal to one half the short diameter. Third, the thickness of nut, which is equal to the diameter of the bolt.

In the following suggestions for the drawing of hexagonal heads, it should be remembered that the rounded type is a sphere cut by six planes parallel to the axis, while the chamfered head may be considered as a cone similarly cut.

22. To draw the rounded hexagonal head and nut. Fig. 27. Having determined H, or the short diameter, and drawn the edges, lay off the thickness of head, and describe the top with a radius of twice the diameter of bolt.

To obtain the arc *ABC*, determine point *B*, which is equal in height to *K*, and through it describe the required arc with radius equal to *MN*, using care to have *C* and *A* of same height. The fine dotted lines show the precise method of finding points *A* and *C* by obtaining the long diameter.

Fig. 28. Figure the short diameter, and obtain the long diameter geometrically as shown by the dotted lines. (In small bolts, or drawings to small scale, the long diameter may be made equal to 2*D*.) The edge *SL* is equidistant from *VW* and the center line, and equal to *VW* in length. Through *S* describe arc *ORS* concentric with curvature of top. Through *S* and *V* describe arc *STV* with radius equal to *LW*.

Fig. 29. This differs from the preceding only in that the thickness is equal to the diameter of the bolt. Observe also that the curvature of the top begins at *G* instead of on the center line.

23. To draw the chamfered hexagonal head and nut. In drawing the chamfered head or
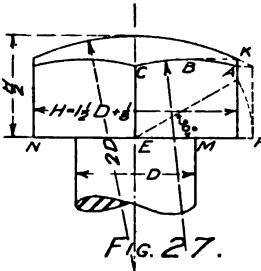
FIG. 27.
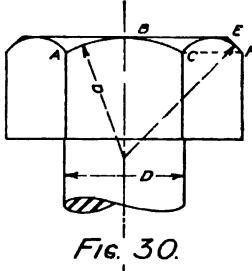
FIG. 30.
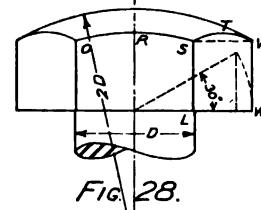
FIG. 28.
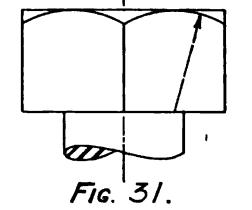
FIG. 31.
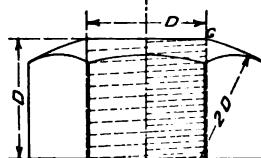
FIG. 29.
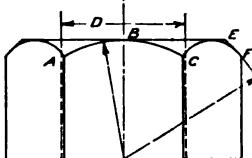
FIG. 32.

nut across corners, as in Figs. 30 and 32, describe ABC tangent to top with radius equal to diameter of bolt. From the same center describe arc EF, point F being equal in height to C.

24. Heads and nuts drawn in connection with the parts which they unite should, in general, be shown across corners. This will prevent errors in the allowance to be made for hubs and washers as it gives the maximum space required for the head. The necessity for observing this is at times so great that the bolt is required to be drawn across corners in all views in which it may appear. In sketching bolts, and in the making of bolt lists, it is better to represent them across flats, as they are more easily drawn and dimensioned.

Nuts should be drawn on the thread for which they are designed, and represented in working position.

25. Fig. 33 illustrates a bolt with check nuts and washers. It is a common practice to make both nuts of the same thickness, and equal to three quarters of the diameter of the

bolt. The more proper form, however, is to make the thickness of the nut sustaining the load equal to the diameter of bolt. Observe also that the outer nut is chamfered on both faces. This might be done in all cases; but polished parts united by bolts having heads and nuts so chamfered are not as easily wiped,
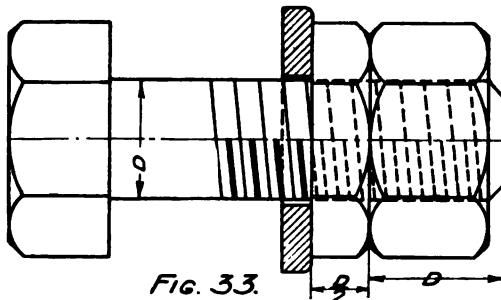
FIG. 33.

since the oil and dust are likely to lodge under the corners. The necessity for chamfering the outer faces is very great, as otherwise the sharp corners would cause difficulty in handling and soon become marred. The proportions of the head are the same as in Fig. 27.

For a table of standard washers see page 20.

26. Square-headed Bolts and Nuts. The proportions for hexagonal heads are usually observed for the square also, save in the radius for the curvature of the top, which is better to be two and one half diameters.

In Fig. 34, the arc ABC is concentric with
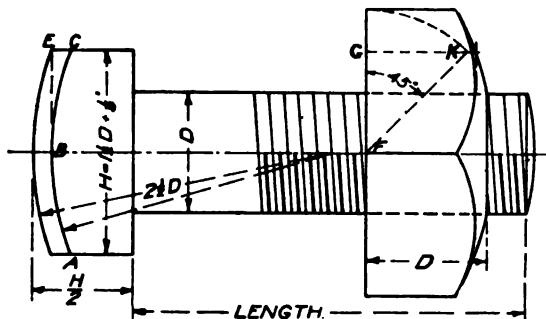
Fig. 34.

the top, and is described through the point B, which is equal in height to E. In drawing the head, or nut, across corners, the geometrical method may be used as shown, remembering that FG is equal to half the short diameter,

and FK half the long diameter. Or the long diameter may be made equal to one and one half the short diameter in small bolts, or where accurate work is not required.

27. Screws, Tap Screws, Machine Screws. The term screw is usually applied to all classes of bolts without nuts. They are named from the distinctive character of their heads, and from the functions which they perform. The term Tap screw, or Tap bolt, has come to have the limited meaning of a screw with a hexagonal or square head of standard size, not otherwise classified. Also, the term Machine screw is limited to screws of small size which are designated by number instead of by diameter.

28. Cap Screw. Fig. 35. A type of tap screw with hexagonal head, and usually finished, having extra thickness of head and·less distance across flats than the standard. It is designed for caps, and is suitable for places where adjustment is necessary.

29. Set Screw. Fig. 36. This is used to prevent the motion of a machine part by pressing against a second piece. The character of
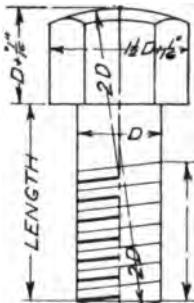
Fig. 35.
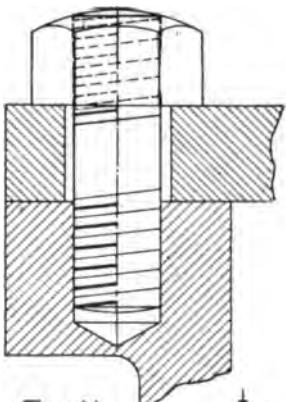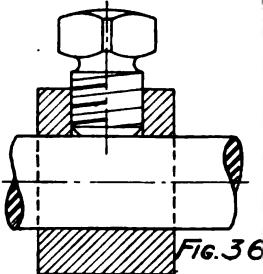
Fig. 36.
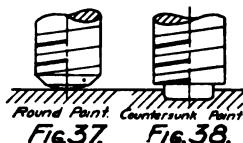
Round Point. Countersunk Point.
Fig. 37. Fig. 38.

Fig. 39.

Fig. 40.

Fig. 41.
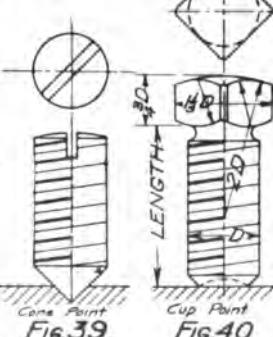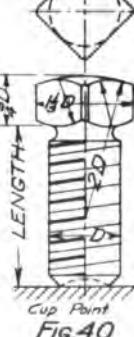
the end will therefore be dependent on the nature of the resistance desired. If friction alone will suffice, the end should be made as in Fig. 37, the radius of the point being 4 diameters. If a fixed position which will not admit of adjustment is desired, the types of Figs. 38 and 39 may be used. The cupped end illustrated by Fig. 40 comprises the advantages of both types, since it will admit of any degree of adjustment, but it makes a circular cut in the shaft or slide.

The head is usually square and the distance across flats made equal to the diameter of the screw. The decrease in the diameter under the head is to facilitate the cutting of the thread.

30. **Stud Bolt, or Stud,** is a screw threaded on both ends and provided with a nut, as in Fig. 41. It is used in places where frequent removal is undesirable and where the unscrewing of the nut will free the fastening. It is commonly used for cylinder heads where the action of steam or water would rust the thread in the hole and make its removal difficult.

31. Fillister Head Screws. Figs. 42 and 43 represent two excellent types for the draftsman because of the simplicity of their proportions. The type of Fig. 42 is better adapted for countersunk work since a variation in the depth of the hole will not affect the appear-
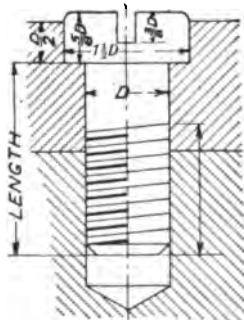
FIG. 42.
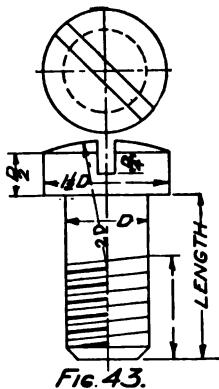
FIG. 43.

ance of the fit. In the end view of a slotted head, draw the lines of the slot at an angle of 45° to make a greater contrast with other lines of the drawing. The standard width of the
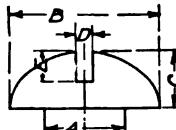
FIG. 44.

ROUND HEAD SCREW

A - diam of body.
B - 1.85A - .005 - diam. of head
C - .75A - height of head
D - .173A + .015 - width of slot
E - ½ C + .01 - depth of slot.
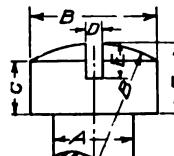
FIG. 45.

OVAL FILLISTER HEAD SCREW.

A - diam of body
B - 1.64A - .009 - diam of head and rad for oval
C - 0.66A - .002 - height of side.
D - .173A + .015 - width of slot
E - ½ F - depth of slot
F - .134 B + C - height of head

FIG. 46.

82 DEG
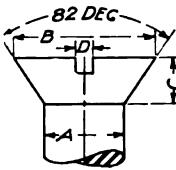
FLAT HEAD SCREW.

A - diam of body
B - 2A - .008 - diameter of head.
C - $\frac{A - .008}{1.734}$ - thickness of head
D - .173A + .015 - width of slot
E - ½ C - depth of slot
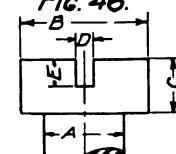
FIG. 47.

FLAT FILLISTER HEAD SCREW

A - diam of body
B - 1.64A - .009 - diam of head
C - .66A - .002 - height of head
D - .173A + .015 - width of slot
E - ½ C - depth of slot

slot is given in Art. 32, but it is sufficiently accurate for drafting purposes to estimate it.

32. Machine Screws. Figs. 44, 45, 46, and 47 illustrate four types of machine screws, the proportions of which were recommended by a committee of the American Society of Mechanical Engineers in 1907. The sizes vary from .06 to .45 inches.

33. Foundation Bolts. Four types are drawn to illustrate the varied uses of such bolts. Fig. 48 is a type used for concrete foundations, when subjected to little strain. Fig. 50 is a Lewis bolt, chiefly used for lifting heavy blocks of stone. It is provided with a single movable key to facilitate removal. Fig. 51 is commonly used where removal is unnecessary. Molten lead or sulphur is poured into the taper hole, filling the space between the taper and the stone. Fig. 49 illustrates a second type for a fixed bolt. The end of the body of the bolt is split and driven into a wedge, thus spreading the end and filling the hole in the stone which is made tapering and slightly larger at the bottom.
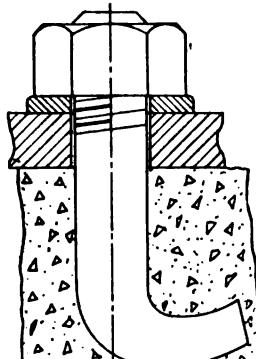
Fig. 48.
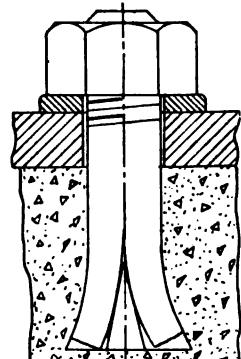
Fig. 49.
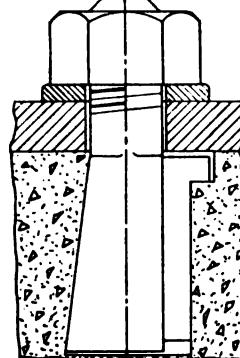
Fig. 50.
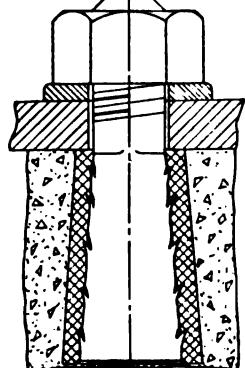
Fig. 51.

34. Washers. The accompanying table gives the sizes for U. S. Standard washers. These will serve for all ordinary uses where special sizes, or cast-iron washers, are not required.

35. Cotter Pins. Various devices are used for preventing the loosening, or accidental removal of a nut. The check nut has been illustrated on page 15, and a great variety of lock nuts will be found in treatises on machine design. A very common method of preventing the nut from backing off is by the spring cotter pin illustrated in Fig. 52. The size and proportion of pins, and their position in the bolt, is given in the accompanying table.

U.S. STANDARD WASHERS

Diam. of Bolt	Diam. of Hole	Diam. of Washer	Thickness	Diam. of Bolt	Diam. of Hole	Diam. of Washer	Thickness
1/4	5/16	3/4	1/16	1 1/8	1 1/4	2 3/4	5/32
5/16	3/8	7/8	1/16	1 1/4	1 3/8	3	5/32
3/8	7/16	1	5/64	1 3/8	1 1/2	3 1/4	11/64
7/16	1/2	1 1/4	5/64	1 1/2	1 5/8	3 1/2	11/64
1/2	9/16	1 3/8	3/32	1 5/8	1 3/4	3 3/4	11/64
9/16	5/8	1 1/2	3/32	1 3/4	1 7/8	4	11/64
5/8	11/16	1 3/4	1/8	1 7/8	2	4 1/4	11/64
3/4	13/16	2	1/8	2	2 1/8	4 1/2	11/64
7/8	15/16	2 1/4	5/32	2 1/4	2 3/8	4 3/4	3/16
1	1 1/16	2 1/2	5/32	2 1/2	2 5/8	5	7/32

FIG. 52.

Cotter Pin

A	3/8	1/2	5/8	3/4	7/8	1	1 1/4	1 1/2
B	3/16	3/16	3/16	3/16	3/16	1/4	3/8	5/8
C	1/2	3/4	1	1	1 1/8	1 1/4	1 1/2	1 3/4
D	3/32	3/32	7/64	7/64	7/64	9/64	11/64	7/32

CHAPTER 3

GENERAL RULES FOR MAKING DRAWINGS

36. Technical drawing is a graphic language, and may best be studied by subjecting its use to laws similar to those governing other languages, for like them, it has its orthography, grammar, and literature. Its orthography consists of the various types of lines ; its grammar is the art of representing objects upon planes, and is known as orthographic projection ; and finally, its literature, consisting of the practical application of these principles to the completed drawings which we are required to read and write. But in this, as in all languages, we cannot be governed entirely by laws, but must familiarize ourselves with the idioms and conventional methods of the day, remembering always that it is simply a medium for the expression of our thoughts.

A drawing fulfills its object only when it clearly sets forth the ideas to be expressed, and in no wise misleads the reader to whom it is especially addressed. If it fails to do this, it is a poor drawing, regardless of the fact that it may conform to established laws, and be executed with the greatest precision and elegance. A drawing should be regarded as a business letter to the mechanic, and must first of all be brief, having as few lines and figures as possible. It must completely express the idea, omitting no lines or views necessary to attain this end. It must contain nothing that may mislead, even though it may be necessary to violate the laws of projection. The character of the drawing must be determined by the use to which it is put. If a free-hand sketch is sufficiently comprehensive, and will in every

way serve the purpose of the finished draw-
ing, it is a waste of labor to make the latter.
On the other hand, no pains should be spared
in the execution of the drawing if it will
better express the designer's conception. No
portion of such work should be carelessly
done, even in the free-hand sketch, or draw-
ing ; for although a sketch may consist of few
lines and be comparatively rude, it must not
be thoughtlessly executed. Again, the drafts-
man must consider the class of mechanics to
whom his drawing is addressed. He should
anticipate their wants, and, to a certain extent,
guard against mistakes which may arise from
their ignorance. Experience alone will make
a man proficient in the use of graphic lan-
guage, but a knowledge of the laws governing
it will greatly facilitate its acquisition.

The development of machine drawing, dur-
ing the last few years, has resulted in the in-
troduction of many methods and technicalities
which were not formerly required. The tech-
nical part of architectural drawing has never
necessitated such rigid conformity to laws
concerning the arrangement of views, methods
of sectioning, figuring, and other details ; and
it is for this reason that many apparent inno-
vations have necessarily been made upon the
old established systems of drawing. No one
change has caused more discussion than the
rigid adherence to the representation of all
objects in what is known as the third angle of
projection, that is, the placing of the top view
on the top of the sheet, the view of the right
side on the right hand of the sheet, etc. ; in
short, placing the view nearest to the face
which it represents. But this has now passed
the stage when the advantages to be derived
from this method are questioned.

This treatise aims to teach such principles
and methods as will enable one to acquire fa-
cility in graphic expression, but avoids de-
tailed information relating to special draft-
ing-room systems. It recommends certain
types of letters, character of titles, size of
paper, and treatment of subjects, for the pur-
pose of simplifying the instruction and avoid-
ing the confusion incident to greater freedom

in interpretation; but it does not aim to instruct the prospective draftsman concerning the best methods of conducting a modern drafting room with its complications of conventions, systems of cataloguing, details of administration, and other features peculiar to the varied demands made on this most important department. Such knowledge must come from practice in the special field which the engineer may elect to enter, but whatever or wherever his occupation, he must first learn to read and write graphics.

37. Drawing Paper. The quality of the paper should be excellent, and such as will enable the erasure of inked lines without injury to the surface. Even though the lines be not inked, it is easier for the novice to work on a moderately heavy paper with a hard surface. The size of the paper is usually determined by standards peculiar to each office, and is largely dependent on the uses for which the drawings are designed. For the problems of this book the sizes of 10 × 14 and 14 × 20 inches are recommended, and nearly all of the work may be done on the smaller size. These dimensions are for the margin lines only, the size of the paper being as much greater as may be desirable. From one half to one inch margin is sufficient.

38. Tracing. The record drawing, or "original," which is filed in the drafting room, is commonly one from which copies can be made by a reproducing process such as blue printing. By reason of this, tracing cloth has come into general use for replacing the inked paper drawing of former days, the tracing being made from a penciled drawing.

Tracing cloth is usually furnished with one surface glazed and the other dull. Either side may be used, but as there is difficulty in erasing from the dull side it is better to ink on the glazed surface. Penciling must be done on the dull surface. As the cloth absorbs moisture quite rapidly, it shrinks and swells under varying atmospheric conditions. Because of this, large drawings, which require considerable time to complete, should be inked in sections, as the cloth will require frequent

adjustment in order that its surface may be maintained smooth and in contact with the paper drawing.   Only the best quality of cloth should be used, as the cheaper kinds are improperly sized and absorb the ink, thereby causing blots.   If the ink fails to run freely on the glazed side, dust a little powdered pumice stone, or chalk, on the surface and rub it lightly with a piece of chamois skin or cloth. Care should be used to completely remove it from the surface before inking.

Inked lines may be removed from the glazed side by means of a sharp knife and a hard rubber, or by dusting a little finely powdered pumice on the lines to be erased and rubbing them with the end of the finger, or a piece of medium soft rubber.   As the pumice becomes soiled, replace it with fresh powder.   In erasing inked lines from the dull side, use the hard rubber.   Penciled lines may be removed by the ordinary pencil eraser, or by means of a cloth moistened with benzine.

39. Character of Lines.   Fig. 53.   All penciled lines should be as fine as is consistent with clearness, and the full line used as much as possible.   If the drawing is to be inked, full penciled lines may be used in the place of dotted lines wherever confusion will not be caused thereby.

The fine line is used for all visible lines of an object which are not to be shaded.

FINE LINE.
SHADE LINE.
DOTTED LINE.
CENTER LINE IF BLACK.
CENTER LINE IF RED.
DIMENSION LINE IF BLACK.
DIMENSION LINE IF IN COLOR.
WITNESS LINE.
AS DIMENSION LINE.
SAME AS DIMENSION LINE.
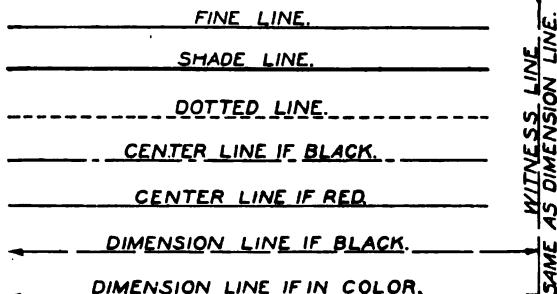
FIG. 53.

The shade line is used to assist in the reading of a drawing by suggesting the relation of the surfaces.   It is used for visible lines only.

The dotted line is used to designate the invisible lines of an object, and is never shaded. It requires more care in the making than other

lines. The dots or dashes should be about $\frac{1}{16}''$ long, and the space between them about $\frac{1}{32}''$. These lengths must not be increased, however long the line may be. Much of the clearness and beauty of a drawing is dependent on the evenness of this class of line.

Center lines are represented by a dot and dash line, the dot being about $\frac{1}{16}''$ long, and the dash about $\frac{3}{8}''$ long. Or, if the line be drawn in red or blue ink, it should be full and fine. Center lines should extend beyond the surface on which they are drawn.

Dimension lines are drawn in dashes about $\frac{3}{8}''$ long and very fine. Or, if drawn in a color, the full fine line may be used. But in either case the witness point or arrow must be pointed and black, as in the figure.

Witness lines are used to indicate the extent of the surface measured when the dimension line falls outside of the surface. The character of these lines should be the same as the dimension lines.

Other classes of lines, such as imaginary lines, traces of cutting planes, etc., may be designated by dashes and two or more intermediate dots. But if there is any question likely to arise concerning the meaning of a line, it should be clearly explained by a note.

Border lines seldom require to be made heavier than the shade lines of a drawing.

Section lines should be of the same width as the fine lines of the drawing.

40. Shade Lines. By some draftsmen the use of shade lines is condemned, while others consider a drawing incomplete without them. Both err in adopting either system to the exclusion of the other; for while shade lines may be useless on many drawings, there are others which would be incomplete without them. The draftsman must decide the question for each drawing which he makes, always using them when they may assist in the reading of the drawing, but otherwise omitting them.

The only practical direction that may be given for the method of using them is to shade the right-hand and lower edges of all surfaces, remembering that in the case of contact between surfaces, the line represents the sur-

face nearest the observer. Where the surfaces are flush, the division line must be fine. Never shade the intersecting lines between visible surfaces of the same piece, as illustrated by the division line of the faces of a bolthead. Shade the lower right-hand quadrant of outside circles and the upper left-hand quadrant of inside circles. Do not permit the shade line to encroach on the surface which it bounds.

Cylindrical surfaces are frequently illustrated by fine lines only, when shade lines are used on other surfaces. This method is equally adapted to the illustration of a complex piece having an insufficient number of views or lacking in detail.

41. Line shading. It is often necessary to express the character of a surface more clearly than would be done by the simple outline, or by the use of shade lines. This is ordinarily accomplished by the use of line shading. Figs. 54 to 63 illustrate the method of shading the more common surfaces. In studying these methods, and in applying them to the practical drawing, it should be observed that

the best effects are frequently produced by the fewest lines; and the more we are able to reduce the number of lines of all types, the better the drawing. By the system here shown, much of the cylindrical and conical shading might to advantage be done by a section liner, which in the case of large surfaces would insure more regular work.

In shading large cylindrical surfaces such as Fig. 54, use only fine lines for the upper portion. Increase the space between the lines quite rapidly, and stop at about one half of the radius from the top. The shading of the lower part may be begun at a distance of about one quarter of the radius from the center. These lines may be spaced equally, although the appearance is somewhat improved by increasing the space for the first two or three lines. The cylindrical effect is produced by increasing the width of the lines until near the bottom, when they are slightly decreased in width in cylinders of large diameter. Fig. 56 illustrates the section of a cylinder, which, being a concave surface, necessitates the draw-

ing of the darker shade lines at the top, but in other respects the method of shading is the
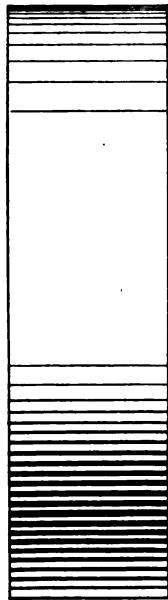
FIG. 54.
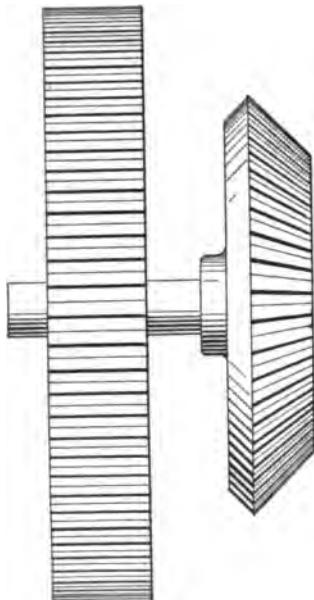
FIG. 55.

same. In the shading of small cylinders the effect is often improved by shading the lower

side only. Compare Fig. 58 with the shaft of Fig. 55.

Bell-shaped surfaces are frequently shaded as in Fig. 57, but that of Fig. 58 involves no circular arcs, and for small pieces is equally good.
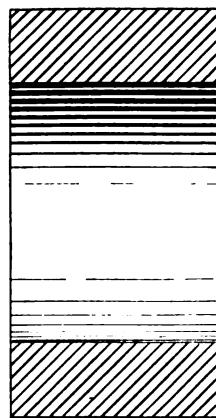
FIG. 57.

FIG. 58.

FIG 56.
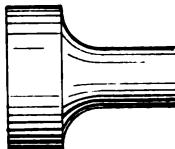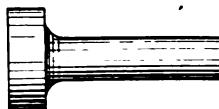
Spur and bevel gears, Fig. 55, may also be represented in a simple manner by shading the surface on which the teeth are to be shown with alternate light and heavy lines. The

maximum space is governed by the thickness of the teeth which is approximated only.

Fig. 59 represents a cone shaded by parallel lines in a manner similar to the cylinder. The usual method of doing this, by drawing all of the shade lines radiating from the vertex, is very difficult, requires more lines, and rarely looks as well.

The pipe shown in Fig. 61 illustrates the method of grading the lines so that the upper and left-hand portion shall represent the illuminated parts. Had the bend been to the right, the shading would have been more simple. The conical portion of the pipe flange shows yet another method that may often be used to advantage. The system used for the shading of the sphere, Fig. 62, will be apparent from the illustration.

It is rarely necessary to shade plane surfaces, and it should be avoided when possible. When necessary to emphasize the fact that a plane is inclined to that of the paper, the method of Fig. 60 may be used.

Fig. 63 illustrates a method for representing
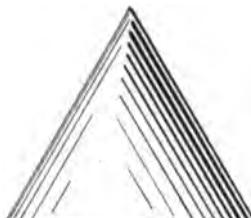
FIG. 59.
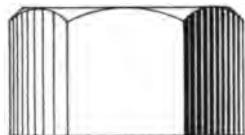
FIG. 60.
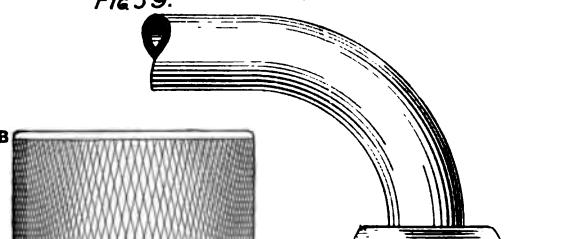
FIG. 61.
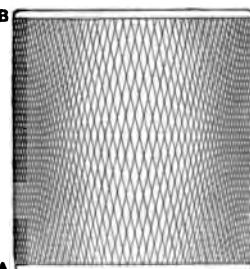
FIG. 62.

FIG. 63.

knurled surfaces. The angle of the cross lines must be varied to conform to the ratio of diameter to length of surface, for it will be observed that no change is made in the spacing until a series of equidistant lines has been drawn from A to B.

42. Method of penciling the drawing. Locate main center lines according to lay-out sketch, and begin to draw the view which best illustrates the object.

Next locate leading lines and surfaces. If the subject be the headstock of a lathe, draw the spindle, fix the position of bearings and pulleys, and then proceed with the drawing of the casting. If a stub-end drawing is required, as in Fig. 98, page 53, lay off the dimensions for the principal lines in much the same order as indicated by the letters alphabetically arranged. First, the diameter and length of the box, A, and B ; then the position of end of rod C, depth of rod, keys and key ways, intersections, etc.

Omit minor details until all else is finished. If a bolt, key, spring, curve of intersection, or any other such detail occurs, its position may be marked, but the drawing of it should be deferred until all else is proved correct.

Do not complete the views separately, but having one well begun, commence the drawing of others. In this manner errors are more readily detected, the drawing of each view becoming a check to the others.

Ink no part of a drawing until the penciling be complete. In a complicated drawing, students are often tempted to ink a view, or part of a view, which they feel confident to be correct, before quite finishing the drawing. This should never be done.

43. Inking. A drawing is inked for the purpose of making the lines more distinct and the drawing more easily read. It serves to differentiate the various classes of lines, to aid in the reproduction of the drawing, by blue printing and similar processes, and finally for the preservation of the drawing. It is not a necessity, however, since clearly penciled lines made with a 3 H or 4 H pencil will serve for the making of good blue prints, and the lines

may be protected from erasure by spraying the surface with a light coat of thinned lacquer.

The order to be observed in the inking of a drawing is as follows: Ink all circles and circular arcs, beginning with the smallest. This includes all fillets and rounding of edges. If shade lines are used, shade each arc at the time of inking it. It will be observed, then, that the width for both fine and heavy lines is determined by the shading of the first circular arc. Do not use too fine a line, remembering always that the drawing must be distinct even after much use, and possible abuse. Next, ink all other curved lines, such as lines of intersection, etc. Finally, ink all fine lines, both full and dotted, beginning with the horizontal lines at the top of the drawing, then ink the vertical lines from left to right, after which all inclined lines. Lastly ink the heavy, or shade lines, in the same order.

Section lines should not be drawn until the figuring is completed.

In the final cleaning of the sheet, it should be borne in mind that many of the auxiliary lines, such as construction lines, may be useful to the pattern maker, or possibly to the draftsmen at some later day. Thus it is frequently well to leave these lines on the drawing, even though it may present a less neat appearance.

44. Lettering. The subject of lettering is of first importance to the draftsman, and he should acquire facility in the use of some distinct type which may be rendered free-hand.

The accompanying types are such as may be recommended to students and draftsmen as acceptable in regular practice, and should be written without the aid of instruments.

Large and small capitals may be used in the place of the capitals and lower case, as illustrated. In such case the height of the small capitals should be two thirds of the height of the large capitals, or the same as the lower case letters. Notes are more easily read if capitals and lower case are used, while for titles and headings capitals alone may be used.

The height of the letter must be varied to meet the requirements of each drawing, but it

is seldom that the letters for a title need be more than $\frac{3}{16}$'', or the small letter of notes less than $\frac{1}{16}$''. This type is quite easily written by means of a hard-wood stick, preferably of orange or box wood, sharpened to a point like a pencil, the size of the point being governed by the desired thickness of line. In using this stick care should be taken to have the ink very black and somewhat thick in order to obtain the best results.

The student is referred to the treatise on "Freehand Lettering" by Frank T. Daniels, A.M.B., "Technical Drawing Series," for a full consideration of the subject of lettering.

45. Scales to be used. The scale to which a drawing is made is usually dependent on the size of the paper which is required to be used.

The scales commonly used by machine and architectural draftsmen are as follows :

SCALE	STATEMENT ON THE DRAWING
Full size	. Scale : full size.
One-half size	. Scale : 6″ = 1 ft.
One-fourth size	. Scale : 3″ = 1 ft.
One-eighth size	. Scale : 1½″ = 1 ft.
One-twelfth size	. Scale : 1″ = 1 ft.
One-sixteenth size . . .	. Scale : ¾″ = 1 ft.
One-twenty-fourth size . . .	. Scale : ½″ = 1 ft.
One-forty-eighth size . . .	. Scale : ¼″ = 1 ft.

The first four and the sixth of these scales may be read from a scale graduated as in Fig. 64, but the others require graduations of forty eighths of an inch. A form of scale commonly used and having all of these graduations is illustrated by Fig. 65, but it is objectionable by reason of the great variety of scales and the liability to error by reading the wrong one. Moreover the triangular form is not so easily read as the flat type.

In using the graduations of Fig. 64 for other than the full, or half size, the following method should be employed: In laying off quarter size dimensions consider each quarter-inch division on the scale as one inch, and subdivide the quarter inches for the fractional
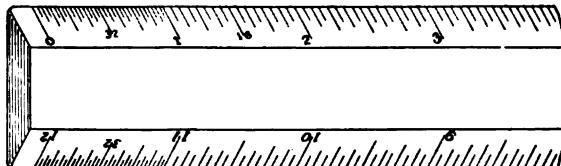
FIG. 64.

FIG. 65.

divisions of an inch. Thus if it is required to measure 17¾ at this scale, lay off 17 quarter inches, and to this add three quarters of the next quarter of an inch. This will be found much more simple than the mental operation of obtaining the quarter part of 17¾″. With

a little practice this scale may be read with as great facility as the type represented by Fig. 65. In a similar manner measurements may be made at one-eighth and one-sixteenth scale.

Beside the above scales, the engineer's or decimal scale is used. In this type the inch is divided into 10, 20, 30, 40, 50, 60, 80, and 100 parts, which divisions usually signify so many feet to the inch. This scale is largely used for topographical drawing.

46. The lay-out of the drawing. Having put down the paper and ruled the margin, obtain a "lay-out" of the pieces to be represented. This consists in the making of an outline sketch of the various parts and views to be put on the drawing, so that ample room shall be provided for each piece, and the whole be symmetrically arranged. This operation is usually neglected by students, and inevitably leads to trouble and the loss of much more time than would be required for the preliminary sketch. Where a number of details are to be put on a drawing, as shown on page 86, provision must be made for the proper

marking of each piece, as well as the necessary dimension lines. If the detail consists of many small pieces, much more space should be allowed than would be sufficient for the pieces only, as the titles alone may require more space than the drawing of the pieces. If provision for each part, and the necessary views, be not made before the drawing is begun, the draftsman may discover, when it is too late to rectify the mistake, that some piece has been omitted, thus requiring an entire sheet to be devoted to this piece, or the redrawing of the whole.

The method of doing this and the character of the sketch required is fully treated in Art. 96, page 68.

47. Number and arrangement of views. The discussion of the arrangement of a sheet leads to the consideration of the number and arrangement of views. The only rule for guidance in this matter is to draw as few views as shall be consistent with the interpretation of the idea, but enough to accomplish this fully. In the valve drawing, page 68, one view is sufficient for the complete repre-

sentation of the object, while in the drawing of the Back Rest, Fig. 118, page 85, two views are barely sufficient for the rapid reading of the drawing. The character of the views has also much to do with the number required; thus, a sectional representation will frequently give more information than two or three outside views.

The views should bear such relation to each other as that already prescribed for the orthographic projection of objects in the third angle, the top view on the top of the sheet, the view of the right side of the object to the right of the sheet, etc. A good rule to observe for attaining this end is to place the view nearest the face represented.

In making a drawing to be used for assembling only, omit as much detail as possible.

Parts which are fully represented on one view need not necessarily appear on the other views.

Draw nothing that may mislead or that does not assist in expressing the idea.

When a written note will serve the making

of a second view, do not hesitate to insert it.

In general, show mechanism in its working position, with the parts sustaining their proper relations to each other. Thus, in drawing a valve, let it be either wide open, or closed. In showing a steam cylinder, draw the piston at extreme end of stroke, and the valve in its proper relation to the piston.
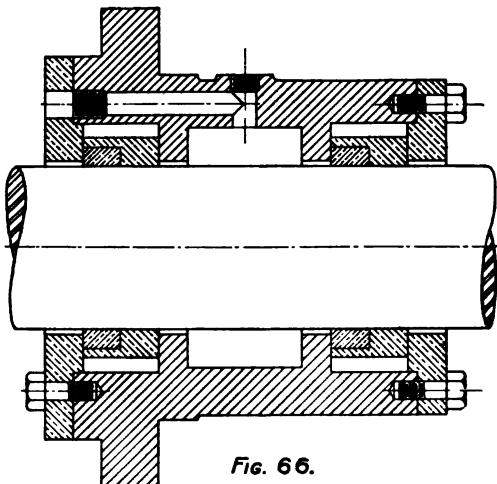
FIG. 66.

CHAPTER 4

SECTIONAL VIEWS

48. The use of a section. To fully represent all the details of an object it is frequently necessary to make a sectional view, or section, as it is commonly termed. This is a representation of the object after having been cut by an imaginary plane, and with that part of the object lying between the plane and the observer removed so as to give an unobstructed view of the inner portion of the sectioned piece.

49. Representation of the sectioned surface. The surfaces cut by the plane are outlined by full lines, and then indicated as lying in the plane by drawing across this area equidistant parallel lines, usually at an angle of 45°. By changing the direction and character of these lines, a clear distinction can be made between contiguous pieces, and the character of the material also indicated. Figure 66 illustrates the application of these principles.

The regulating of the space between the section lines is frequently done by the eye, but may be more easily and accurately accomplished by using a section liner. This is an instrument by means of which a triangle, or straightedge, is made to move through equal spaces which may be adjusted to fit the conditions. The space between these lines is dependent on the area to be sectioned and the effect desired, no specific rule for which can be given. Care should be used in determining this space, and especially to avoid making it too small, since there is an almost universal tendency to err in that direction. Previous to sectioning the drawing, it is well to draw a few lines on another paper at the proposed distance apart, so as to judge the spacing.

50. Notation for section lining. Figs. 67 to
76 illustrate various types of section lining
suitable for indicating the different kinds of
material. Save in the case of cast iron there
is no agreement among engineers as to the
material which each type of sectioning shall
designate. Such a standard was proposed,
but fortunately failed of adoption, since it
would have added one more complication to
the intricacies of modern graphics. It must
be borne in mind that the English language is
always available, and should be used whenever
it will serve to express one's ideas better than
graphic language.

In the illustrations of this book the follow-
ing notation has been used for section lines;
but this is for the convenience of students
and instructors and not for the purpose of ad-
vocating a system.

Fig. 67 represents cast iron; Fig. 68
wrought iron or steel; Fig. 69 composition
metal, such as brass, bronze, etc.; Fig. 70 is
used to section an invisible surface and should
be used sparingly. Fig. 71 represents Bab-
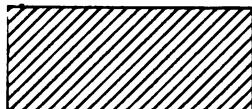
FIG. 67.
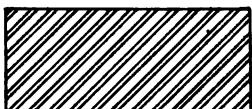
FIG. 68.
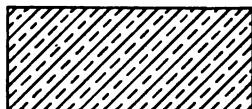
FIG. 69.
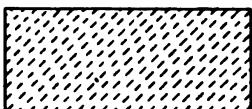
FIG. 70.
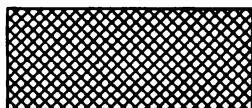
FIG. 71.
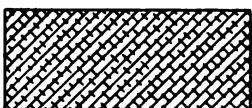
FIG. 72.

FIG. 73.
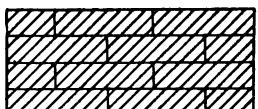
FIG. 74.
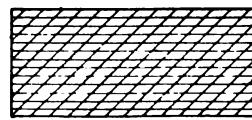
FIG. 75.
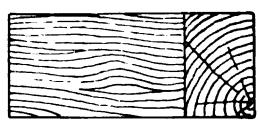
FIG. 76.

bitt's or other lining metals which are usually poured into place while in a molten state. Fig. 72 is not designated. Fig. 73 is used to produce a sharp contrast with other sectioning, and is frequently useful on Patent Office drawings. Fig. 75 is used for insulating material. Fig. 76 is for wood, with and across the grain. Fig. 74 is for brickwork.

Other types of sectioning may be devised for special cases, but it rarely happens that the variety here represented will not serve. The author does not recommend any sectioning involving the use of both fine and heavy lines.
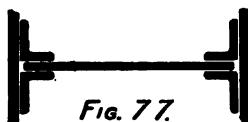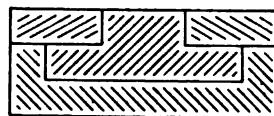
FIG. 77.   FIG. 78.

51. When the sectioned surface is very small it is customary to represent it as in Fig. 77, by making the cut surface black and with a slight space between the contiguous surfaces.

Sectioned surfaces may also be emphasized by making the section lines fall short of the limiting lines of the surface, as is done in Fig. 78.

52. Colored sections. Previous to the introduction of blue printing, and other reproducing processes, the sectioned surfaces were represented by tinting them with distinctive colors which might be characteristic of the material, but it necessitated the making of a tracing which had to be section-lined as at present. This process was both rapid and satisfactory so far as the drawing was concerned, and where the practice was adopted of sending the paper drawing into the shop, and retaining the tracing for the office file, it provided the workman with a drawing which was more easily read than a blueprint with conventional section lines. The following tints are commonly employed for colored sections: Paine's gray for cast iron; Prussian blue for wrought iron; Indian yellow for brass; Burnt sienna and burnt umber for wood; Indian red for brick.

53. Relation of the section to other views. Although it is customary to draw the section apart from other views, projecting it in the same manner, lack of space sometimes necessitates drawing it on the view to be sectioned,
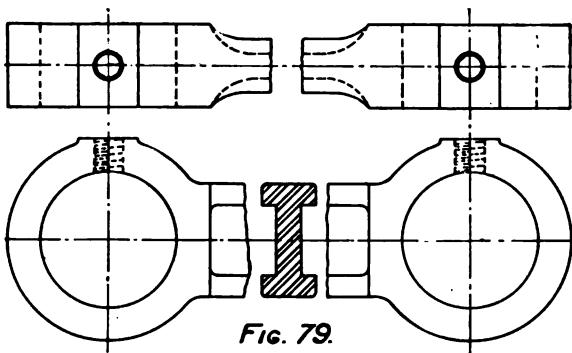
Fig. 79.

as in the case of the arm illustrated by Fig. 83, page 41. This method is frequently used in architectural drawings. In general, it is clearer to make a break in the view and place the sectional view in this place, as in Fig. 79.

54. It is sometimes necessary to represent a portion of a surface lying in front of the plane of the section and on the part supposed to be removed. In such cases it is necessary to change the character of the lines to something distinctive of an irregularity, such as a dash and dot line.
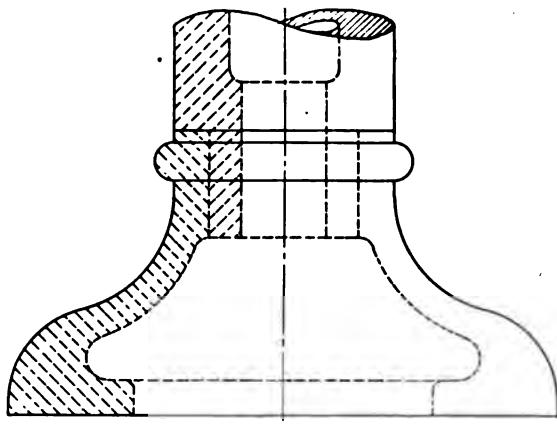
Fig. 80.

55. Dotted sections. At times it is necessary to represent an object by a full, or external

view, when a section is also required to explain some small detail. Instead of making a separate sectional view it may suffice to dot the obscure section either by the method of Fig. 67, one half of which shows the section by dotted section lines while the other half rep-
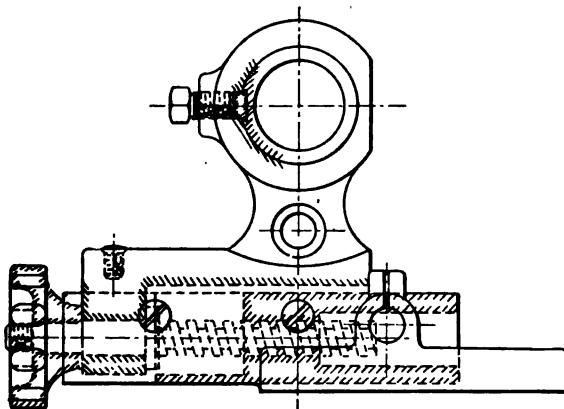
FIG. 81

resents the section by a dotted outline only ; or by that of Fig. 81 in which the dotted outline is emphasized by a series of short dashes.

This second method may be used to advan-

tage when penciling a somewhat complicated drawing which may, or may not, be shown in section when inked. Thus in the representation of the lathe tail stock shown by Figs. 122, and 123, pages 90 and 91, the lines of the penciled drawing would be more confused if the section lines were omitted until the inking was completed. It is desirable, therefore, that they be indicated in pencil after the manner of Fig. 81 ; but these lines should be so carefully and lightly sketched that the erasing of them will be unnecessary after the completion of the drawing.

Section lines should never be ruled in pencil.

56. Choice of cutting planes. In representing an object in section, pains should be taken in choosing the position of the cutting plane so as to enable all details requiring explanation to be shown in the clearest possible manner. As this is one of the most important subjects relating to the art of graphic expression, the student should make a careful study of all drawings relating thereto, and observe the following general principles.

57. A section of a symmetrical piece should be suggestive of symmetry. Fig. 82 illustrates a cylindrical piece with hubs, ears, and ribs. Two sectional views are shown, the upper being the conventional, and proper representation, while the lower is drawn in strict conformity to the appearance which would be made by a plane *AB* passing through the center. From the upper section our first impression is of a cylindrical piece with a flange having certain hubs and ribs attached thereto, while in the lower section all is confusion, and it conveys no idea of symmetry.

Fig. 83 is a correct sectional and face view of a gear. Although the plane of the section is on *AB* and cuts through one arm and a tooth, yet only the hub and rim are sectioned. The key, too, is shown as though it were on the side instead of the top of the shaft in order to preserve the symmetrical appearance of the shaft and hub.

Again in the case of the stuffing-box gland, Fig. 84, page 42, the ears are better shown in full, if they are small in comparison with the
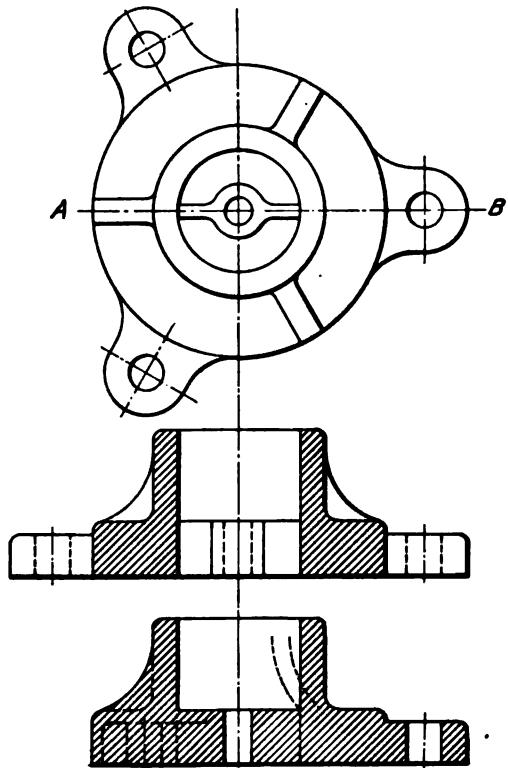
FIG. 82.
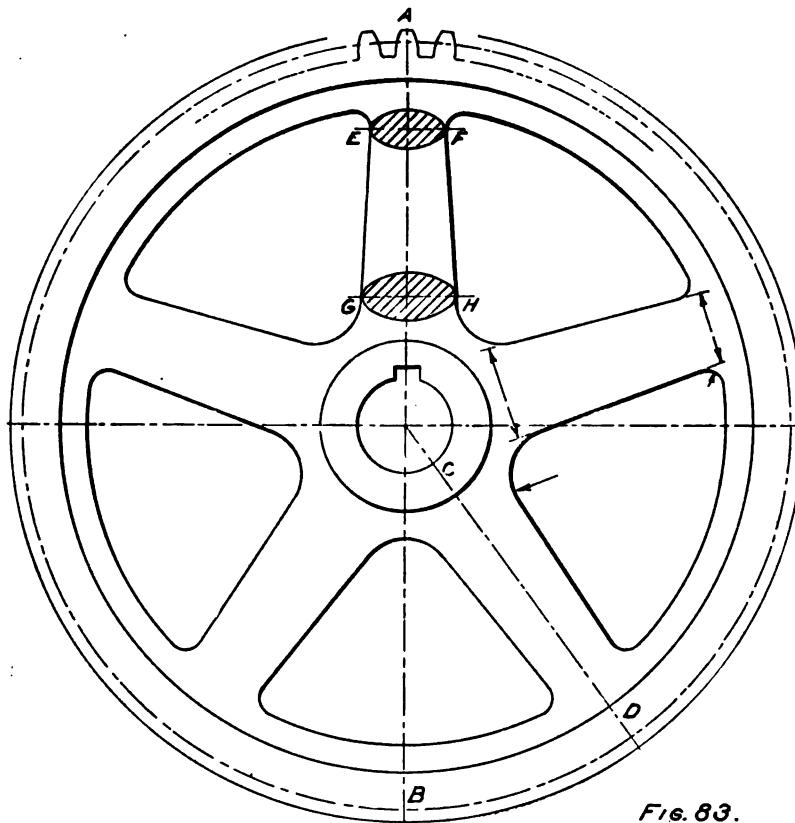
Fig. 83.
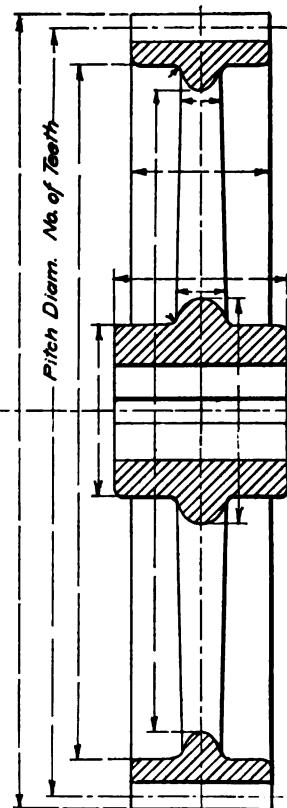
flange diameter.   Discretion must be used in showing the flange bolts, since they may be drawn in full, or shown dotted as in the figure; but in either case their true relation to the cylinder is suggested by drawing them at their correct radial distance from the center.   To project the bolt shown at the left, from its position as drawn in the top view, would add nothing to the information required, but tend to mislead.

58.   **It is not necessary to section all that lies in the cutting plane.**   In the sectional view of the gear, Fig. 83, page 41, the shaft, key, arm, and tooth are shown in full although they lie in the plane of the section.

Also, in the section of the connecting rod, Fig. 98, page 53, the top view represents a section made by a horizontal plane passing through the center of the rod, but only the boxes and the end of the strap are shown in section, because a section of the rod would add nothing to the clearness of the drawing.   In general, do not section a shaft, key, bolt, gear tooth, rib, or arm of a wheel.

FIG. 84.
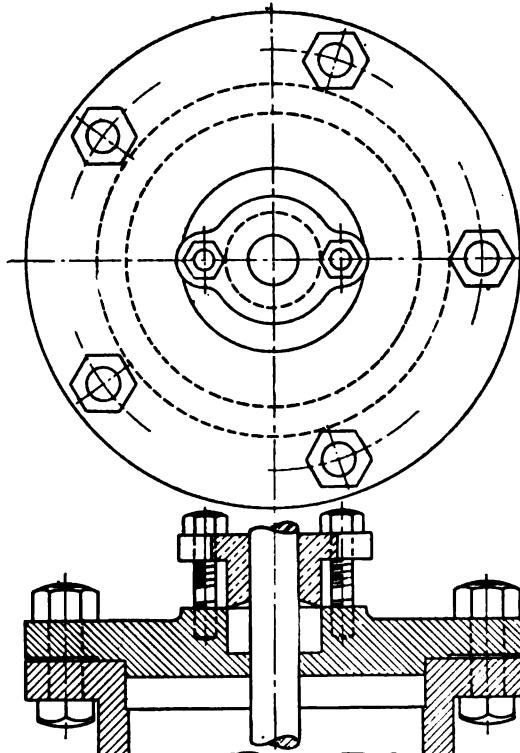
59. The plane of the section need not be continuous. The sectional view of the tail stock of a lathe, page 90, is an excellent illustration of the application of this principle. Fig. 122 is a section on planes *AB* and *CD* of Fig. 123. This enables one to obtain two sections in one view, while producing no confusion in the drawing. Indeed, the practice is so common that the note concerning the planes on which the section is made is frequently omitted.

60. The portion of the object lying beyond the plane of the section need not be shown if it be undesirable. In Fig. 84, page 42, the flange bolts lying beyond the plane are not shown, since it would add to the labor, and produce confusion as well. In general, however, it is better to show the projection of visible lines and surfaces which are beyond the plane of the section.

61. Broken sections. When a portion of a rod, bar, pipe, or other symmetrical piece is shown as broken, the section should be suggestive of the shape. Fig. 85 represents a cylindrical rod; Fig. 86, a bar of rectangular section; Fig. 87, a pipe; Fig. 88, a rod of wood. The outline of these sections may be drawn with an ordinary pen, but the lines should not be jagged save in the representation of wood.
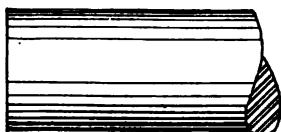

FIG. 85.
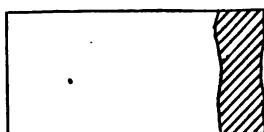
FIG. 86.
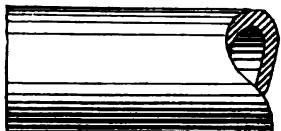
FIG. 87.
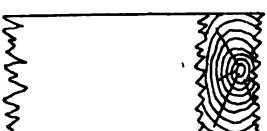
FIG. 88.

62. An excellent method of distinguishing the section of a rib from the general section is shown by Fig. 89, which is a vertical section through a Corliss-type steam engine cylinder.
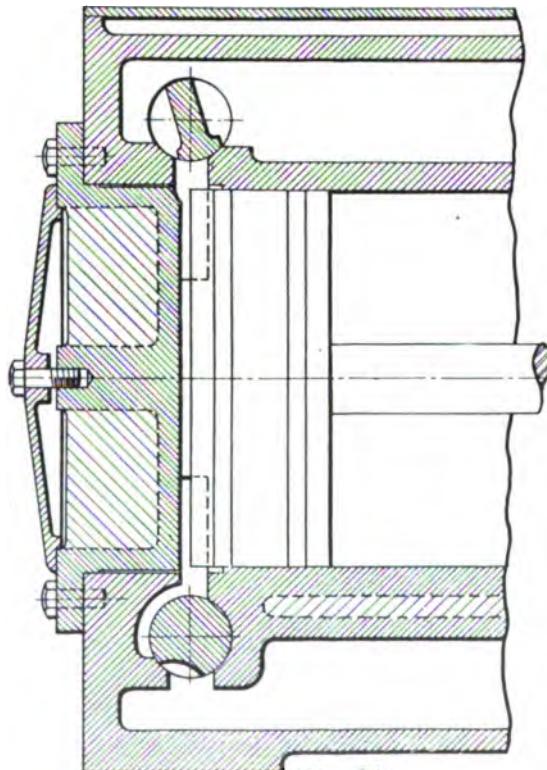
Fig. 89.

The ribs of the cylinder head are easily distinguished from the flanges by using a coarser sectioning for the former.   Similarly, the web joining the barrel of the cylinder with the exhaust chest is clearly separated from the general section.   In using this type of sectioning omit the drawing of every other section line on the rib, or on the arm.

63. Figs. 90 to 93 illustrate some of the foregoing principles relating to sections.   Fig. 90 is a free-hand sketch of an armature spider. Fig. 92 is a face view, and Fig. 93 a section on *AB.*   Fig. 91 is also a section on *AB,* but in violation of the rules just considered.   Attention is first called to the difference between the sectional views of Fig. 91 and Fig. 93. Both are sections on the same plane, but Fig. 91 is a literal interpretation, while Fig. 93 is an idiomatic, or conventional one.   From Fig. 93 we may see at a glance that there are two turned pieces, the hub *C* and flange *D.*   These are united by ribs or arms, *E,* having at their ends projections marked *F,* the details of which can only be obtained from the face view.   The
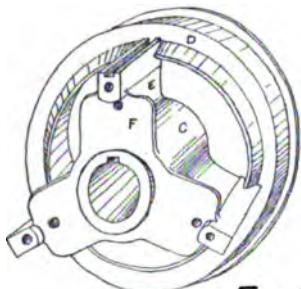
FIG. 90.
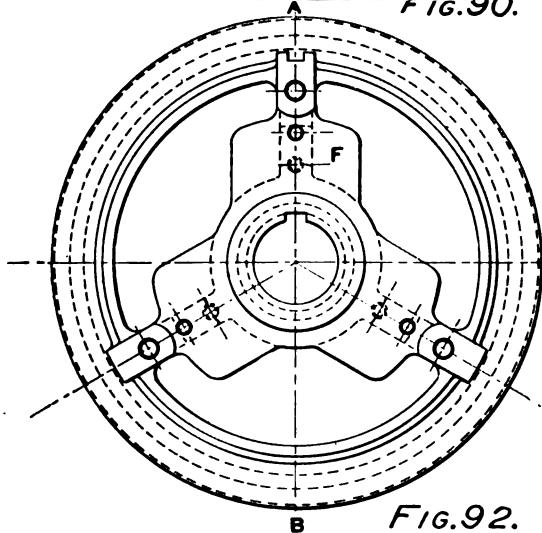
FIG. 91.

FIG. 92.
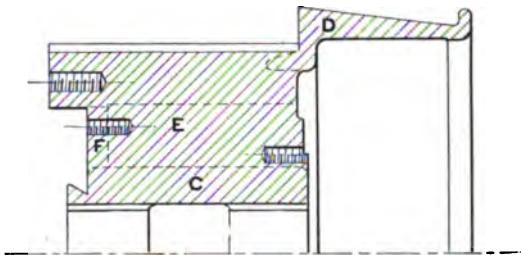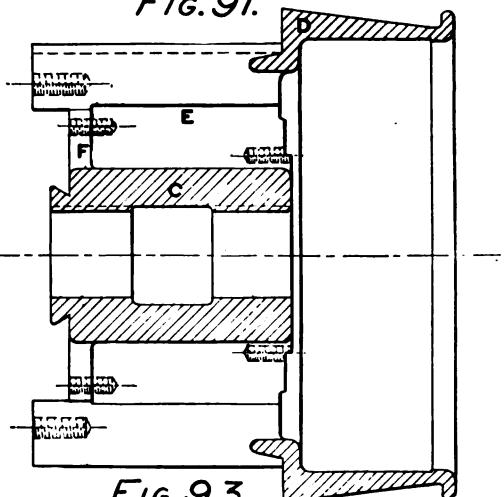
FIG. 93.

section of Fig. 91 confuses the details by representing all of the parts included in the section, and separated by dotted lines only. In Fig. 93 it will be observed that the arms are shown alike on both sides of the center line, although there are but three, and this for the purpose of suggesting symmetry. Also note that the key ways in the hub and arm of Fig. 93 are dotted, while those of Fig. 91, being in full, give a false idea of the diameters.

64. Another illustration, showing the importance of well-chosen planes for the section of an object, is that of the piston in Fig. 94. Two half views with suitable sections enable one to completely illustrate all of the details. In the upper view the follower and junk ring bolts are drawn in the plane of the section, which is on *AB*; but no confusion is caused thereby, as they do not appear in section, the hub for the latter being drawn in full, and the recess for the former being dotted. The lower view consists of two full views and a sectional view. Note that the division line between these views is not a full line.

Piston Body
Packing Ring
Junk Ring
Packing Spring
Packing Ring
Follower
Follower Bolt

Section on A-B

Piston with follower on

Section on C D

Follower removed
Packing Spring

STEAM PISTON
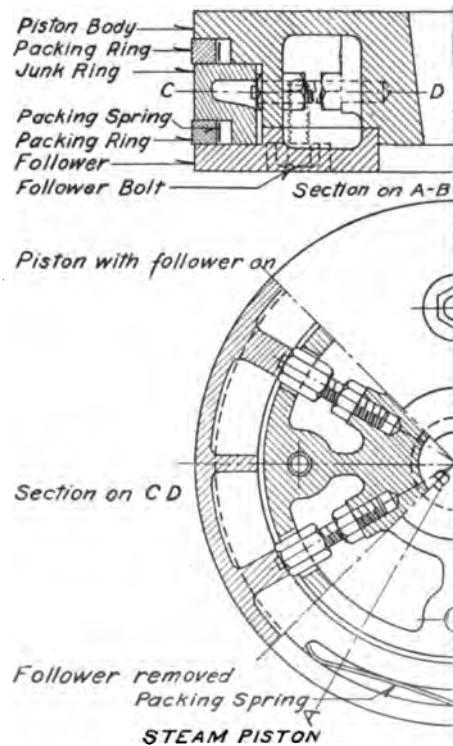
Fig. 94.

CHAPTER 5

DIMENSIONING

65. After the inking of a drawing is completed, and before the section lines are drawn, the dimension lines must be made. This is the most important part in the making of a drawing, and requires the greatest care and experience. Unfortunately, at this stage of the work the student, and not unfrequently the draftsman, becomes weary, and the subsequent operations are too often hurriedly and carelessly performed. While it may frequently be necessary to make haste in the dimensioning of a drawing, it must never be hurriedly done; and the most scrupulous care should be exercised in the drawing of every dimension line and in making and checking every figure.

Three questions arise in the treatment of this subject:

First — What character of lines and figures are used to express the dimensions?

Second — Where shall the dimensions be placed?

Third — What dimensions are required?

Explicit instruction can be given concerning the first, but the second and third require experience, a knowledge of construction, and a full appreciation of the needs of the workmen. Much that relates to the second question will be considered in the first.

66. Dimension lines should be very fine, and may be continuous, or broken. They

will terminate in arrow-points, or witness-
points, which must exactly touch the lines to
which the dimensions are given. The arrow-
points should be carefully made with a fine
pen, as illustrated. An open space may be
left in the line for the figure, but it is not
necessary.

Several methods are used for placing the
arrow-points, as illustrated by the dimension
lines drawn between lines *B* and *C*, Fig. 95.

If a color is used for the dimension lines, as
is sometimes done on a paper drawing, it is
well to use red for the center lines and blue
for the dimension lines.

All dimension and witness lines must be
drawn before writing the figures.

Dimension lines should not be crowded, or
drawn too close to the projection lines of the
object, or to the center lines. Neither should
they coincide with these lines.

Avoid drawing dimension lines across wit-
ness lines.

Dimension to center lines and faced sur-
faces.

Dimensioning Tapers and Angles
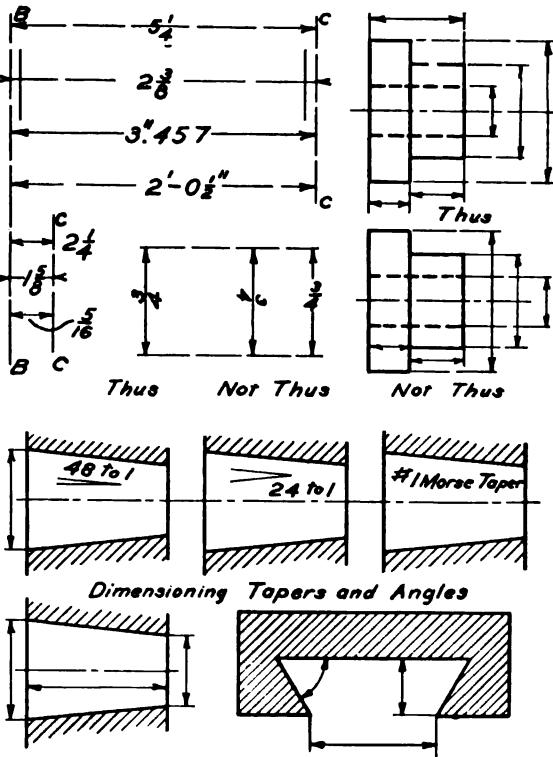
FIG. 95.

If a dimension is given on one view it is generally unwise to repeat it on another view.

67. The figures should be of suitable size, uniform, and perfectly clear. Ordinarily the height will vary from $\frac{3}{32}''$ to $\frac{1}{8}''$, and when written with notes, should be of the same size as the capital letters. The size and character may be similar to those illustrated.

The figures should face the bottom or right hand of the drawing and be written in line with the dimension line, not inclined or perpendicular to it.

When all the dimensions are in inches the inch mark may be omitted, but when feet and inches are specified, use the method suggested by the accompanying figures. It is well to express dimensions which are less than two feet, in inches, and larger values in feet and inches; but no general rule can be made since it is customary to express certain values in inches only. This is the case with steam cylinders, and frequently with pulleys.

Separate the numerator and denominator of a fraction by a line parallel to the dimension line, if the latter is not used for this purpose; but never use an inclined line.

In writing decimals the inch mark may follow the integer, thus emphasizing the position of the decimal point, as $3''.457$.

Never allow a figure to be crossed by a section line or projection line.

If a figure is changed without altering the drawing, affix the word " make," which indicates the draftsman's knowledge of the existing discrepancy in the drawing.

68. Angles and Tapers. The dimension line for an angle is usually an arc with the center at the vertex of the angle. Fig. 95.

If a standard taper is not used, such as is given in the table on page 101, it may be dimensioned as in Fig. 95.

69. The dimensions should always indicate the full size. In connection with this, it is well to note that the scale dimensions of a drawing should never be spoken of, as it would cause great confusion. To illustrate: let us suppose a shaft eight inches in diameter to be drawn one-quarter size. It would then measure two

inches, but should never be spoken or thought of as other than eight inches, the real diameter; and if the draftsman be asked to add an inch to the diameter, it is his business to see that the proper increase is made according to the scale which he may be using. In this case he would have to add one quarter of an inch to the diameter as drawn, but it must always be spoken of as one inch.

70. Circular arcs. Fig. 96 illustrates acceptable methods for dimensioning diameters and radii.

Figure the diameter of a circle in preference to the radius, and draw the line at an angle.

The dimension line should be drawn through, or toward the center of the arc to be figured.

When dimensioning a circle it is customary to draw the lines upward and to the right in order that the figures may be more easily read, but as this is not always possible it is well to reverse the figures at the 60° line as indicated by the dimensioning of the concentric circles of Fig. 96.

The sectional view of a circular piece should
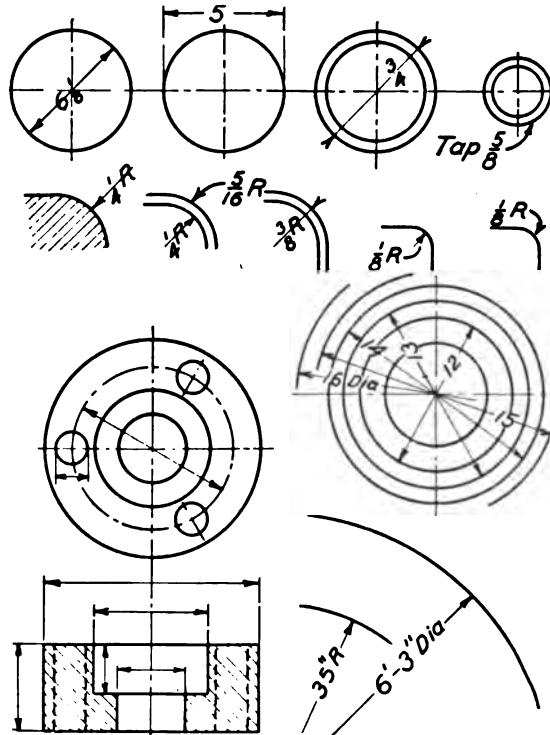
Fig. 96.

be dimensioned in preference to the face view, as it is easier to distinguish the surfaces indicated by the arrow points.

71. Method of indicating finished surfaces. It is not always necessary to indicate the finish of surfaces, but when drawings are very fully detailed, and the work of construction much subdivided, complete instruction for finish must be given. It is customary to indicate finish by writing the letter " f " on the projection line of the surface to be finished, or if the surfaces are small and closely related they may be included in one note, as in the accompanying illustration, Fig. 97.

Colored inks are also used to designate finish, lines being drawn parallel with, and close to, the projection line of the finished surfaces. This method is somewhat objectionable because of the confusion caused by the increased number of lines, but may be used to advantage on blueprints.

If the character of the finish is to be expressed, a printed note must be made parallel with, and close to, the line of the surface.

72. Explanatory notes are required to supplement the drawing and the figures, in order to completely inform the reader concerning the character of finish, the kind of fit which may be required, gage sizes, character of material,
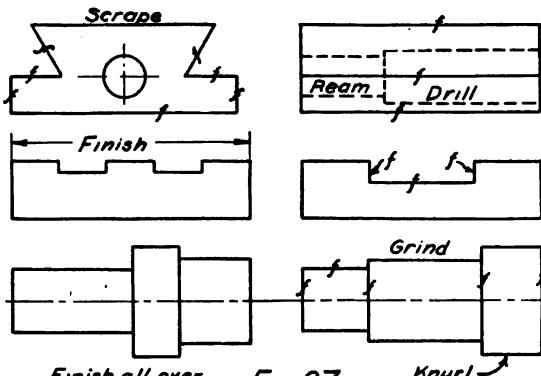
Fig. 97.

number and name of parts, together with other necessary information such as may not have been expressed by the drawing. The same care should be taken with each note as would be used for a title; a uniform height of letters,

proper form, and spacing being maintained. Capitals and lower case letters are more easily read than all capitals. Emphasis may also be obtained by writing the note at an angle. Some of the uses of such notes are illustrated in the following article.

73. Examples of dimensioning. As an illustration of the order to be observed in the dimensioning of a drawing, consider the stub end of a connecting rod, as illustrated in Fig. 98. Supposing the drawing to be in readiness to dimension, we have first to consider the class for whom it is made. In general, the needs of the pattern maker are first to be considered, but inasmuch as the pattern serves for many duplicate pieces the dimension of the unfinished parts may usually be omitted. In such cases the draftsman will provide the pattern maker with a sketch, or tracing, giving the necessary dimensions. This will save crowding the drawing with figures which when once used are not likely to be required again. If the drawing is to be sent to a distance, where detailed information may not readily be obtained from the draftsman, these figures must not be omitted from the drawing.

The requirements of the forge shop may also be met by sketches specially prepared for that department; but the dimensions given for the machinist will ordinarily suffice for the smith. In giving dimensions for either the pattern maker, or the smith, specify finished sizes only, leaving the amount of finish to the judgment of the mechanic. In Fig. 98 dimensions for the machinist only have been given.

The dimension lines were put on the drawing in alphabetical order beginning with the most important, A and B, which determine the size of the crank pin for which the connecting rod was designed. Next locate the end of the rod by C, after which completely figure by dimension lines marked D, E, F, G, H, I, J, K, L. Then consider the gib and key by O, P, R, S, etc. Dimension the set screw and strap, and finally, the boxes, if dimensions given for other parts do not include these.

The dimension lines being completed, the center lines should be inked, after which make

CONNECTING ROD END
FIG. 98.
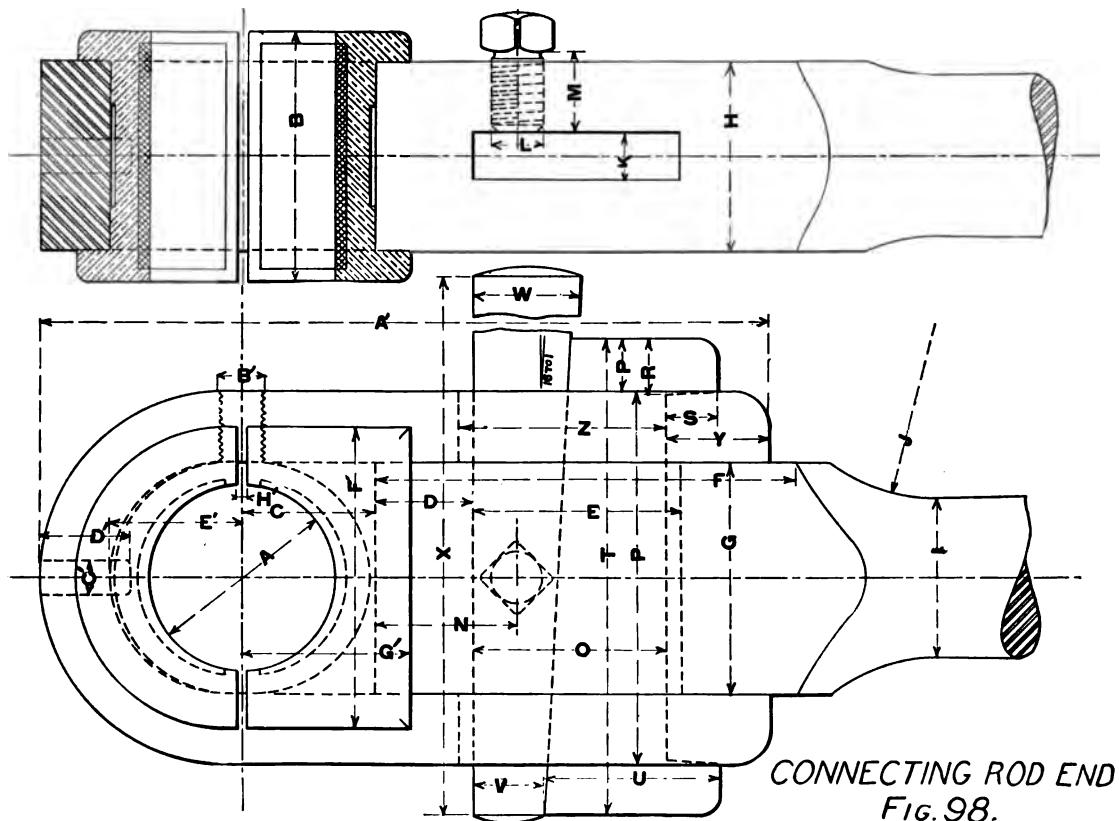
arrow-points and figures. The drawing should then be cleaned, and finally, section lined.

74. Dimensioning a hand lever. Fig. 99 illustrates the dimensions and instruction necessary for machining a hand lever, but does not give the dimensions for the casting, as that
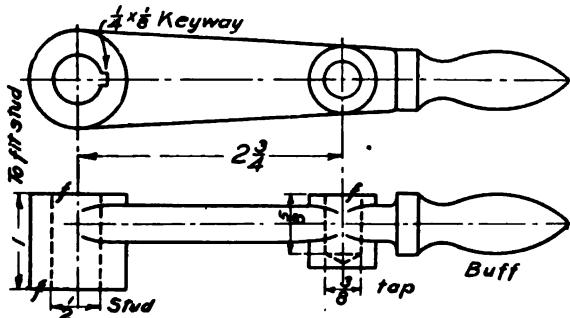
F I G. 99.

would detract from the clearness of the drawing, and they are not required for the machinist. The center distance of the hubs, $2\frac{3}{4}''$, may not be necessary, as the drilling is to be central with the hubs, in which case it may be indicated as $2\frac{3}{4}'' +$. The character of the holes in the hubs

is shown by the notes, one being reamed to fit a $\frac{1}{2}''$ standard plug, and the other tapped for a $\frac{3}{8}''$ screw. The finish of the handle is specified, denoting the absence of turning. The finished surfaces are indicated by "f".

75. Dimensioning a shaft. Note the following features which are illustrated in Fig. 100. The journals are located from one end, and the distance between them is given. In some cases it might be desirable to give the distance between centers of the journals. The overall dimension is also given on the lower side of the shaft. The subdimensions are given on the upper side. Beginning at the left, the shaft is threaded, eight to an inch. The next section has a $\frac{3}{8}''$ key, the depth of which may be obtained from the table, page 102. The journal is ground, and the diameter is given in thousandths, indicating extreme accuracy. The fifth section is designed to be a forcing fit for a pulley, the diameter of which must be obtained by the machinist. A taper pin is also used, and located from the collar which is in contact with the pulley hub.

76. Finding dimensions. The figure for any special dimension may be more readily found by first looking for the arrow-point which must touch one of the lines between which the dimension is required. If the point is not to be found on one view, seek for it on other views, and, failing to find it, the figure may be declared missing. To illustrate: suppose the combined width of gib and key of the connecting rod, Fig. 98, page 53, is required. Beginning at the top of the key we find that the first arrow-point leads to the dimension W, the second to the dimension E, and the third to the required dimension O. This method will greatly facilitate the finding of figures on complicated drawings, and enable the workman to determine quickly whether or no a figure be missing.
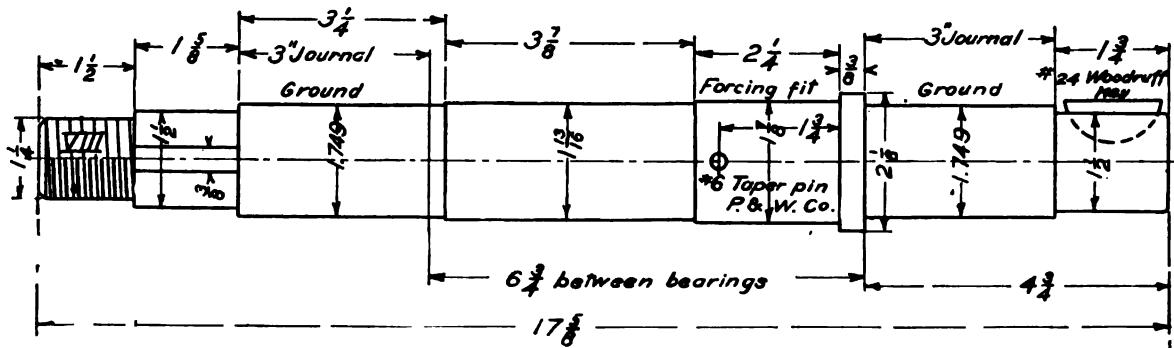
FIG. 100.

77. Standard measurements, gage sizes, character of fit and treatment of material· are suggested in the following list of notes.

MACHINE AND WOOD SCREWS: give diameter by screw gage.

PIPE: give nominal diameter.

TUBE: give outside diameter and thickness by gage, or in thousandths of an inch.

WIRE: give diameter by gage, or in thousandths of an inch.

SHEET METAL: give thickness by gage, or in thousandths of an inch.

WIRE CLOTH: give number of meshes per linear inch, and gage of wire.

SPRING: give outside diameter, gage of wire, and coils per inch when not compressed.

ROPE: give largest diameter.

CHAIN: give diameter of rod used for link.

SPECIFY CHARACTER OF FIT: as force, drive, or shrink.

SPECIFY TREATMENT OF METAL: as hardened, tempered, case-hardened, blued, etc.

78. Titles. The information contained in the title is of great importance, but varies much in detail, being dependent on the systems of office administration. The following data, however, should appear on all drawings, and is usually placed in the right-hand lower corner of the drawing.

The title should designate first, the subject-matter of the drawing; second, the scale; third, the date, being that of the completion of the drawing; fourth, the signature of the draftsman. In shop practice it will also contain some or all of the following information: the signatures of the tracer, checker, and chief draftsman; the name of the firm; the time number and filing number; references to other drawings, and subsequent alterations; instruction relating to the order.

79. Bill of material. This is a tabular statement descriptive of the stock required for the parts illustrated. It consists of the following: first, an identification number corresponding to a number on the drawing of the piece; second, name of the piece; third, name of the material; fourth, required number of each piece for one complete machine; fifth, other

information, such as the pattern number, dimensions of rough stock, may also be specified.

This may appear on the drawing, or on a special sheet, and include the specifications for several drawings or the entire machine.

80. Checking. The last operation required of the draftsman is that of checking the drawing. This requires a full knowledge of the design, the most exacting attention to every detail, and a systematic procedure in examining the drawing for corrections and additions.

This work may be done by the draftsman who made the drawing, or by one who is appointed for the special purpose of checking drawings. The latter method is more common in large drafting rooms and, in general, is the safer plan, since the professional checker approaches the work with a freshness which the original draftsman is not likely to possess. And, too, he has become expert in the use of systems for the detection of errors.

81. Points to observe in checking. The order indicated in the following is not so essential as the faithful observance of each item.

1. VIEWS. See that the necessary number and character of views have been made; that the proper shop systems have been observed, and that every detail is clearly expressed.

2. NOTES. Examine for completeness, as well as accuracy of statement. See that they are well placed and sufficient in number.

3. FINISH. See that the proper finish marks are clearly indicated, and the character of finish properly and fully stated.

4. DIMENSIONS. Scale all dimensions, and check by computation also. Add subdimensions to check overall dimensions. Compare the dimensions of parts which work together, such as, a shaft and its bearing, or a bolt with the parts which it must clamp. See that no dimensions are omitted and that the workman is not required to compute any dimensions.

5. STANDARDS. Note the uniformity of sizes in bolts and screws, and the conformity to standards in all parts that are standardized.

6. TITLE. Finally, see that all the necessary details which are required to be recorded under this head have been given.

CHAPTER 6

TECHNICAL SKETCHING

82. The term "sketch" too frequently implies inaccuracy in thought as well as slovenliness in drawing, although greater precision in thought and a higher degree of skill is required for the making of a technical sketch than is necessary for the instrumental drawing. This is not due to the dexterity required for the clever handling of a pencil, but to the difficulty in executing a drawing without mechanical checks to errors of judgment in the representation; and also, because of the necessity for a more concise expression of the idea than might be required in the drawing. Moreover, a thorough knowledge of projection and the principles of machine drawing are as requisite to technical sketching as to instrumental drawing. Finally, it necessitates a thorough training in observation, which in itself is one of the best educational processes. The enumeration of these difficulties is not for the purpose of discouraging the student, but rather to direct his energies toward gaining a mastery of this most efficient method of technical expression.

83. The sketch should be used whenever it may save the time of making an instrumental drawing and serve equally well for the expression of ideas. It should be freely used in the development of mechanical ideas, serving as a check to one's thoughts, and assisting in the interchange of ideas which are not easily conveyed by written or spoken language. The engineer must make use of this medium for the preliminary studies of new designs, and to direct his subordinates in the elaboration of details. At such times the engineer cannot

resort to the more laborious process of instrumental drawing, but must rapidly express his thoughts by free-hand sketches. Some of these preliminary sketches may be as complete in the important details as the more elaborate drawings which the draftsman must finally make for shop use.

84. Practice in sketching. Practice in acquiring this invaluable art of rapidly and clearly expressing one's technical ideas may be acquired in several ways. That most to be commended is the practice of sketching directly from the object according to the method hereinafter explained. A perspective, or isometric representation, is often useful as a substitute for many views, or to more sharply define certain obscure details; but if the student is unfamiliar with these methods, the orthographic representation will suffice for all cases.

When it is not possible to obtain models from which to draw, a good exercise will be found in a free-hand detailing of the parts of a finished drawing, after which the sketch may be tested by making the assembled drawing from it. A most valuable training, both in sketching and in observation, may also be had from making memory sketches. For this purpose choose some simple model, or the drawing of a plain object, and having carefully studied its details and proportions, set it aside and make a free-hand drawing from memory comprising the necessary views.

85. Order to be observed in making sketches. Three entirely distinct steps are required in making a technical sketch, and it is very important that they be taken separately and in the order specified, as follows: First, the making of the sketches of the several parts; second, the drawing of all dimension lines; third, the measurement of the parts and writing the figures on the dimension lines.

86. First step: having separated the different parts of the machine, sketch each in detail, making it complete in itself, and omitting nothing necessary to a full representation. Do this by making a careful study of the object with a view to obtaining a proper choice

of the number and character of the views to be represented. Then study the proportions with such care that the object could be largely sketched from memory, mentally locating salient features, such as faced surfaces and center lines. Obtain a close approximation to the thickness of the several surfaces, judging the individual parts by the touch. Use one view when possible, but do not overcrowd a view with details. If a portion of a view may be made to substitute the whole, this should also be done. Sketch objects in their working position, when possible, as it is better to suggest the true relation of lines and surfaces, although the dimensions alone are to be relied upon to determine them. When practicable, it is well to sketch those parts which may be mechanically related, so that reference may be readily made from one to the other.

Exercise such care in the making of the sketch as will enable it to be easily understood by any one familiar with the technique of drawing. The character of a sketch too frequently implies the supposition that it is intended solely for the draftsman who made it, and not infrequently many details are omitted, to be supplied by memory. The sketch should be as complete as a drawing in supplying the information which it is intended to convey.

The scale to which the sketch is made is unimportant, and it is not necessary that all parts of the same mechanism be sketched at the same scale ; the proportions, however, must be maintained and the drawing of sufficient size to clearly illustrate each piece while leaving room for notes and dimensions. Frequently the smaller pieces are the more complicated, and should therefore be drawn to the larger scale.

In making sketches first establish the center line and important details as would be done in the making of a drawing and, in general, proceed in a similar manner. The views should be properly related according to the laws of orthographic projection. Complete the sketches of the entire mechanism before putting on any dimension lines.

87. Second step: sketch all the necessary dimension lines with their witness points, but do not figure the sketch. By confining one's attention to the needed dimensions it insures a more thorough dimensioning of the drawing, as one is not diverted from the consideration of the dimensions wanted by the measuring of the pieces and the writing of the figures; it is productive of neater work, since one is not required to handle the pieces which are likely to be coated with oil or covered with dust; it enables the work to be more rapidly and easily done, since it may be executed at the desk, and without reference to the pieces save through the sketch. This method, too, will also involve a critical reading of the sketch, and serve as a check to errors of drawing.

The center lines should be drawn with care, and the position of dimension lines determined as in the case of a drawing, save that in the former case more will be required. Dimension each piece independent of the others. Thus, in the case of a shaft and its bearing,

the diameter of the shaft will appear upon both.

88. Third step: obtain the figures for the dimension lines indicated on the sketch. The sketch and its dimensions should accurately represent the object illustrated. It does not follow, however, that the drawing subsequently made from this sketch will be a duplicate representation of the pieces sketched, in the sense of reproducing every detail of dimensioning, including possible inaccuracies in construction and irregularities due to casting. Drawings made from existing mechanisms are intended to produce that which the machine was designed to be rather than to copy the piece already constructed; but if an attempt be made to suggest these alterations on the sketch, confusion is very apt to arise.

89. Instruction in the use of a pencil. The sketch may be made on plain or section-lined paper, and may comprise one or all the parts of a machine on one sheet. All of the work should be done without the aid of scale, straightedge, or compass.

The pencil should be an H or HH sharpened

to a rather long point for the drawing of fine lines. It should not be held too near the point, since freedom in the movement of the fingers, as well as the forearm, is necessary for free-hand sketching. Since long lines may be more accurately drawn with a motion of the forearm from the elbow, it is desirable to sketch the object in such a position as to permit of drawing the long lines parallel to the lower edge of the paper. The shorter vertical lines may then be drawn with a wrist motion. A little practice in drawing parallel lines, both horizontal and vertical, will be found of value.

Draw the line very lightly at first and correct any portion or the whole by drawing a second line without erasing the first. Finally, reënforce the line sufficiently to make it clear; but the first attempts should be scarcely visible and not require erasing. In this manner draw the center lines and obtain the general proportions and salient features, making all save the final lines so light as to be unobjectionable if not erased.

In drawing circles of considerable size, determine the limits of two perpendicular diameters and indicate four intermediate points in the circumference, after which sketch the curve lightly, correcting it where necessary. It will be found easier to draw a curve with the concave side toward the hand. A judicious selection of views, and freedom in the use of sections, will enable one to avoid the drawing of many circles.

Do not shade penciled lines. Make dimension lines and center lines lighter than lines of the object. Witness points should be small and very clear.

90. Examples of technical sketching. Pages 94 to 96 illustrate the application of the foregoing principles, and suggest methods to be observed in the representation and dimensioning of a considerable variety of pieces. To sufficiently emphasize the center and dimension lines in the plates it was necessary to use the conventions adopted for drawings, but full and very fine penciled lines may be used for all center and dimension lines on sketches.

CHAPTER 7

EXAMPLES FOR PRACTICE

91. The illustrations accompanying these examples are designed to serve as types of sketching and drawing as well as for practice in applying the foregoing principles. The student should acquire facility in reading drawings so that he may quickly obtain an exact idea of each and every detail therein expressed. An excellent test of one's ability to do this will be found in making detail sketches in isometric from a simple assembly drawing. Fig. 103, page 68, and Fig. 114, page 78, will afford good practice for work of this character.

92. It is not intended to prescribe the order in which the examples shall be done, and the treatment of them may be varied to suit the judgment of the instructor. If the drawing is made under the direction of a teacher, a variety of checks should be applied to test the understanding of the pupil. When possible, it is desirable to require drawings to be made from sketches prepared by the student, but in such cases the machine from which the sketches are made should not be accessible during the time of making the finished drawing from the sketches.

A careful study should be made of each problem before beginning to draw, and a layout sketch should be submitted in all cases. See Art. 46, page 33, and Art. 96, page 68.

Air Chamber

Valve Rod
" " Collar
L

Valve Rod
Guide

Inside Cyl.
Head
Stuffing Box
Gland

Tie Rod

4" Discharge

4" Suction

M

K   D

N

2 ¼"

22   1 ½

Four Valves

Cap
Valve Guard
" Stem
" Disc
" Seat
" Plate

Cylinder

Outside Cyl.
Head

Piston Rod
Piston

Foot

Bolt Study
for
6"x12" Pump Cylinder.

H

G   B

C   A

G

J

9
7 ¼

E

F

Fig. 101.

EXAMPLE 1. BOLT DRAWING 65
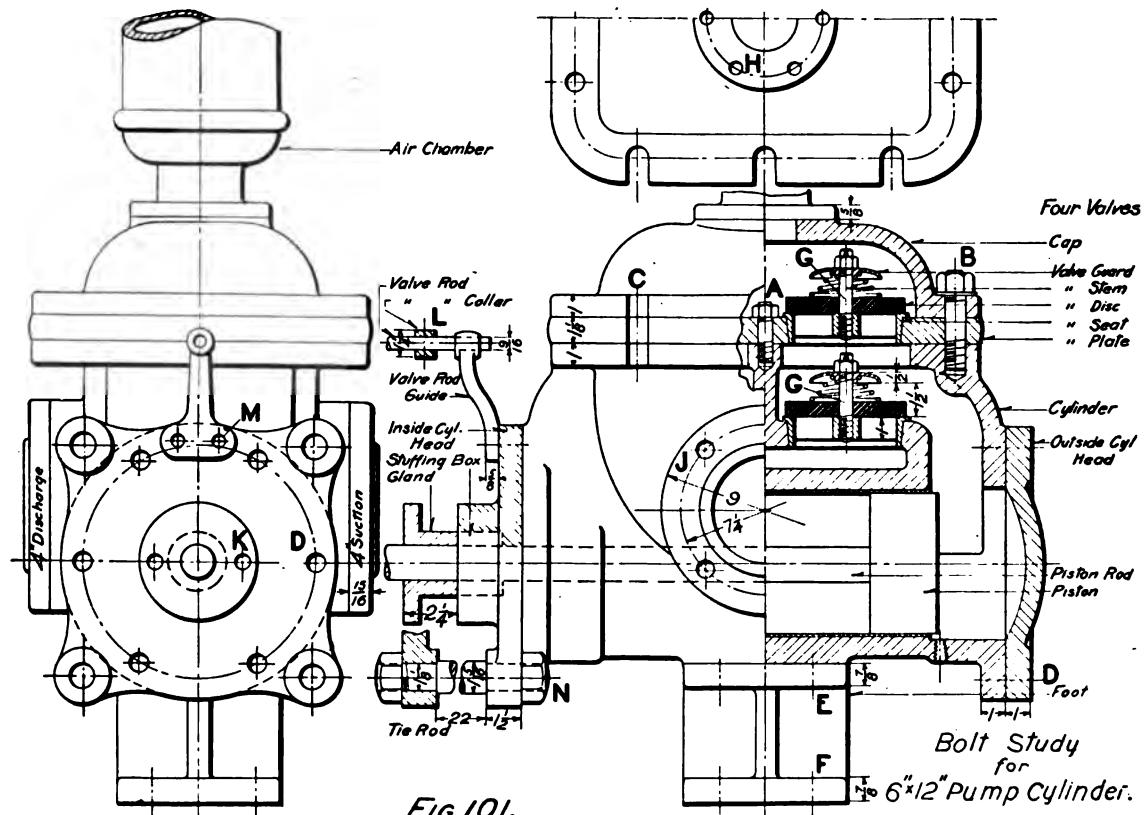
93. Example 1. Fig. 101, page 64. Bolt drawing for a Boiler Feed Pump. Fig. 101 is the drawing of the pump end of a $10'' \times 6'' \times 12''$ Boiler Feed Pump ($10''$ steam cylinder, $6''$ pump cylinder, and $12''$ stroke). The required parts are lettered, and the necessary information concerning these details is given in the following text. To facilitate the drawing of these details it is desirable to make a free-hand sketch of the required pieces, giving the most important dimensions and details, such as: diameter and length of bolts, length of thread and character of head, title, and number of each kind. The space required for each piece should be indicated and a lay-out sketch made. Art. 46, page 33, and Art. 96, page 68. As this drawing will be somewhat crowded, the following arrangement is suggested to facilitate the lay-out. Arrange the sheet for four lines of bolts as follows: First line, N, A, E; second line, K, C, F; third line, B, G, M, L; fourth line, D, H, J, and title.

The drawing will be made on a $10'' \times 14''$ sheet, Art. 37, page 23, which will permit the use of a full size scale. The nuts will be drawn across corners and the heads across flats. Ordinarily this would not be done, but inasmuch as this drawing is to serve as a study of types, it is desirable to introduce considerable variety. The Government standard will be used for hexagonal heads, nuts, and threads. The latter will not be drawn to scale, but represented according to approved conventions. Art. 8, page 6. No part of the pump cylinder should be drawn in connection with the bolts. Provide a $2'' \times 4''$ space for the title in the right-hand lower corner of the drawing.

A. $\frac{5}{8}''$ brass stud with chamfered hexagonal nut for valve plate. Art. 23, page 14. This bolt is made of brass in order to resist the action of the water to which it is subjected. The nut will be drawn across corners and in its working position on the stud. This rule applies to the drawing of all nuts and washers. Make the length of threaded ends of a stud the same when possible. Do not use fractions of less than $\frac{1}{8}''$ for length of bolts or threads.

B. $\frac{7}{8}''$ studs with washers and chamfered hexagonal nuts. Allow for $\frac{1}{16}''$ packing on both sides of valve plate. The washer will be drawn in contact with the nut, and the dimensions taken from the table on page 20.

C. $\frac{7}{8}''$ square head bolts with washers and chamfered hexagonal nuts. These are designed for the same purpose as *B*, their removal being facilitated by the use of slotted holes in the flange which would not be possible for bolts in the position of studs *B*. Art. 26, page 16.

D. $\frac{5}{8}''$ studs with rounded hexagonal nuts. Art. 30, page 17. The specification for a rounded nut signifies a finished nut. It is not customary to use finished heads and nuts with machinery of this class, but the type is used here for practice.

E. $\frac{3}{4}''$ tap bolts chamfered hexagonal heads. Art. 27, page 16. The bolt head will be drawn across flats. Allow sufficient length of thread to prevent the jamming of the thread when screwing up. Observe the thickness of material which is required to be bolted on, as

well as the depth of thread which is necessary. Art. 15, page 8.

F. $\frac{3}{4}''$ foundation bolts, chamfered hexagonal heads and nuts. The foundation consists of 12″ of brick and 4″ of concrete. Use washers $\frac{1}{2}''$ thick with area equal to 20 times the area of bolt. These bolts are not shown on the sketch, but the necessary details are given for determining their length. See page 19.

G. $\frac{9}{16}''$ brass valve studs with nuts and cotter pins. The cotter pin is designed to prevent the possibility of the nut unscrewing by reason of the vibration of the machine, or from other causes. Art. 35, page 20.

H. $\frac{1}{2}''$ tap bolts. Air chamber to cap. Chamfered hexagonal heads.

J. $\frac{3}{4}''$ tap bolts for 4″ standard pipe flange. Chamfered hexagonal heads. See page 100.

K. $\frac{5}{8}''$ studs for gland. Rounded hexagonal nuts. Art. 22, page 12. Special attention is called to the length of the threads on either end. These lengths will not be the same.

L. $\frac{5}{16}''$ square head set screw. Art. 29, page 16.

EXAMPLE 2. BOILER CHECK VALVE   67

Sketch for
1¾" Bronze Check Valve
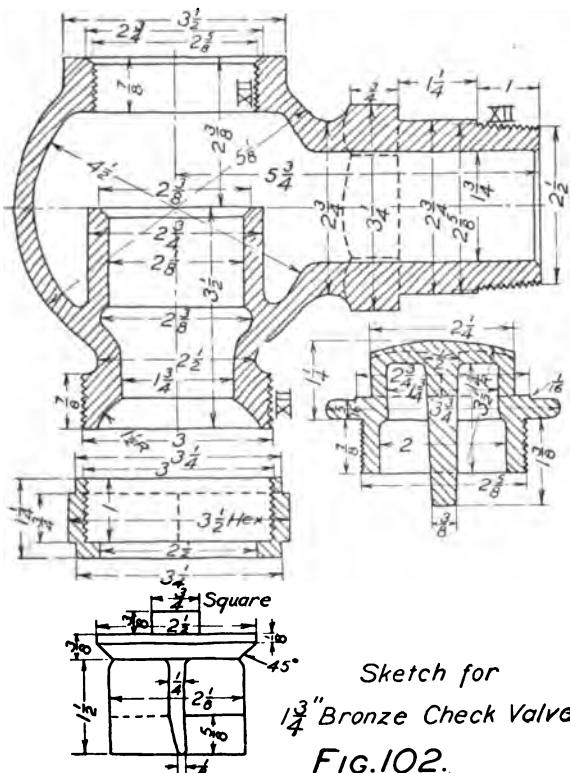
FIG. 102.

M. ½″ cap screws. Valve rod guide to pump head. Art. 28, page 16.

N. $1\frac{5}{16}$″ tie rods. Finished hexagonal nuts. These tie rods are used to bolt the water cylinder to the steam cylinder.

94. Example 2. Fig. 102, page 67. Assembly drawing for a Boiler Check Valve. This is to be shown complete, with the valve on its seat, the cap screwed down, and the coupling nut partly on. One view is quite sufficient for illustrating all details, but it is desirable to draw a side view to obtain the practice. The principal view should be sectioned, and the character of the metal designated by the notation prescribed for section lining. Art. 50, page 36. See that the dimensions are on the drawing before the section lining is begun. See Art. 96, page 68, for method of making the lay-out sketch. Do not pencil dimension lines.

95. Example 3. Fig. 103, page 68. Detail drawing for a 2″ Globe Valve. All of the parts are to be shown separately on one sheet in like manner to those of Figs. 119, 120, pages 86, 87. The lay-out of this sheet will require careful

study, involving the consideration of the number and character of views.   Art. 96, page 68.

A more difficult, but most excellent treatment of this example would be to make a freehand detailed sketch of the valve, figuring the same completely, and then, putting aside the original drawing, make the assembly drawing from the sketches.   Either of these will require much more time than may appear necessary at first, but to faithfully and accurately produce one such drawing is worth a dozen thoughtlessly executed.

96. Lay-out for an assembly drawing of a Connecting Rod. Fig. 111, page 74, illustrates the sketches for a connecting rod of which it is planned to make an assembly drawing on a $10'' \times 14''$ sheet.

It is apparent from the dimensions that a full size representation cannot be made, and in order to determine the scale, as well as the arrangement on the sheet, a lay-out must be prepared.   To do this one should proceed as follows: Having made a careful study of the parts, decide on the arrangement and number

2″ Globe Valve   Fig. 103
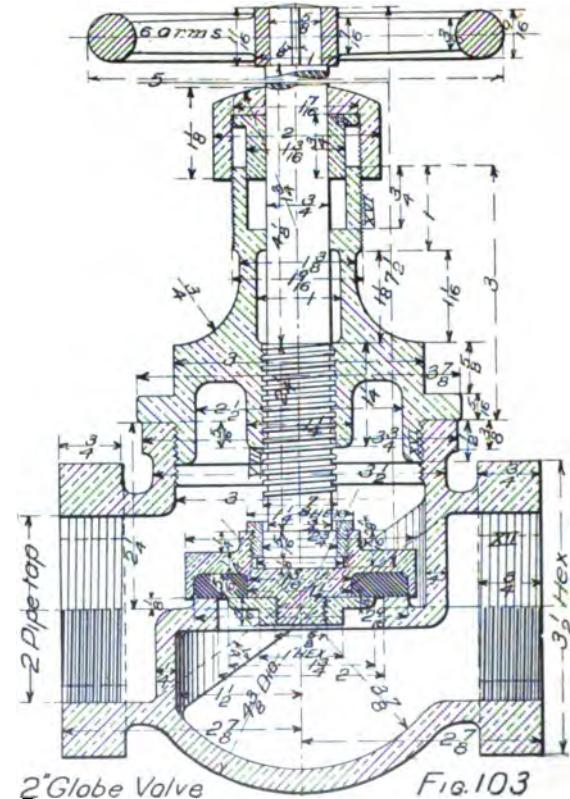
of the views. Fig. 104 illustrates such a lay-out sketch. The minimum number of lines has been used to illustrate the space occupied. Having completed this outline sketch, determine the dimension lines necessary to locate the several parts in their relation to each other and the margin lines. The dimensions having been supplied from the sketches of Fig. 111, it will be seen that $A + B + C$, and $D + E + F + G + H$ will determine the minimum length required, making no allowance for space between the views, and between the views and the margin lines. Similarly, the minimum height, exclusive of clearances, will be $2 M + 2 K$, or $M + N + L + K$, according as $M + K$ is greater or less than $N + L$. These two sets of dimensions will determine the minimum space required for the drawing, and the scale necessary to use. Having decided upon the scale, it will be possible to determine the space between the views, and from the margin lines, not forgetting the title, which must be placed in the right-hand lower corner. Finally, obtain the four dimensions W, X, Y,

Z, which locate the centers from each other and the margin lines. The making and figuring of such a sketch should precede the making of every drawing, however simple.

Layout for the Connecting Rod of Fig III.

3x4 Space for Title
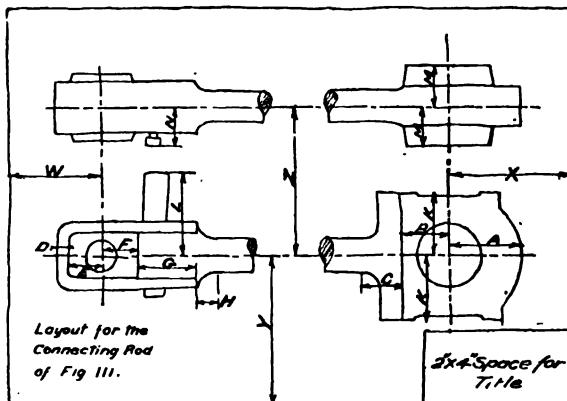
FIG. 104.

97. Problems relating to a Connecting Rod. Before beginning the drawing of a connecting rod, it is necessary that one should have a thorough understanding of the gib and key mechanism for regulating the adjustment for wear. It is also important that one should

review the geometrical conditions governing
the curves of intersection between the bell-
shaped surfaces and rectangular ends of rods.
As the principles involved in the latter are
applicable to many practical problems, it is
desirable that the student should make a
careful study of each of the cases illustrated.

98. The action of a Gib and Key to produce
motion of the strap for taking up wear in the
boxes is illustrated by Fig. 105. *A* represents
the stub end, *B* and *C* the boxes, *D* the strap,
E the key, and *F* the gib. The parts are
shown in such relative position as would exist
in a newly fitted connecting rod. The box *B*
bears against the end of the rod *A*, and is
immovable, all of the motion due to the wear
of the boxes being made by *C*. In order to
move the box *C* toward *B*, the strap *D* must
be made to move to the right. This is accom-
plished by driving down the taper key *E* so
as to increase the distance between the parallel
faces of gib and key ; and since there can be
no motion to the left, the gib is moved to the
right with the strap against which it bears.
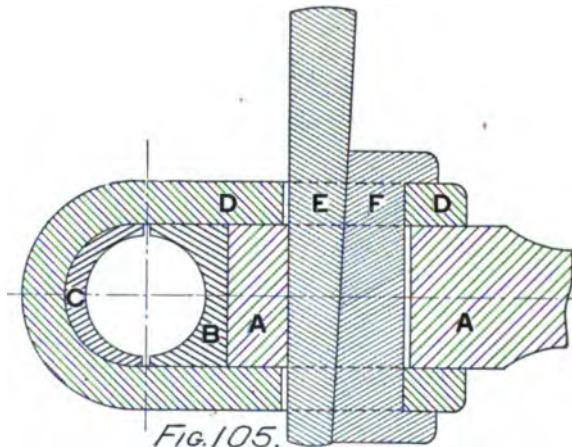
Fig. 105.

**99. To determine the curves in a Connecting
Rod.** Fig. 107 represents a cylinder terminat-
ing in a bell-shaped end, and because the
surface may be generated by the motion of
a line about an axis, it is known as a surface
of revolution. The end view of this surface
is shown as cut by four planes, *AB*, *CD*,
AC, *BD*, parallel to the axis, and the appear-
ance of the object after having been cut is
shown by Fig. 106. It is required to find the

curve of intersection *EFG*, together with a similar curve on the upper surface which will be shown on another view.
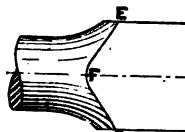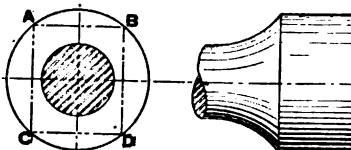
Fig.106. *Fig.107.*

Fig. 108 illustrates the same case without the line shading. Three views of the cylinder with its bell-shaped end are shown, but they are represented as cut by the planes A^SB^S and B^SD^S, producing the intersecting curves $B^FG^FD^F$ and $A^TH^TB^T$, which it is required to find. Since the points A^S, B^S, and D^S lie on the surface of the cylinder and at its intersection with the bell-shaped end, their projection on the other views must be at the points marked by the corresponding letters in these views. The limiting points, *H* and *G*, of the curves of intersection are readily determined by extending the lines B^FC^F and B^TC^T until they cut the curve at the points H^F and G^T.

The top view of the point H^F must lie between A^T and B^T and directly over H^F. Similarly, project G^T on to the front view at G^F. It remains only to determine the intermediate points in the curves. Pass any plane, *KL*, perpendicular to the axis; this will intersect the curved surface in a circle shown on the side view by $O^SP^SM^SN^S$; but this circle
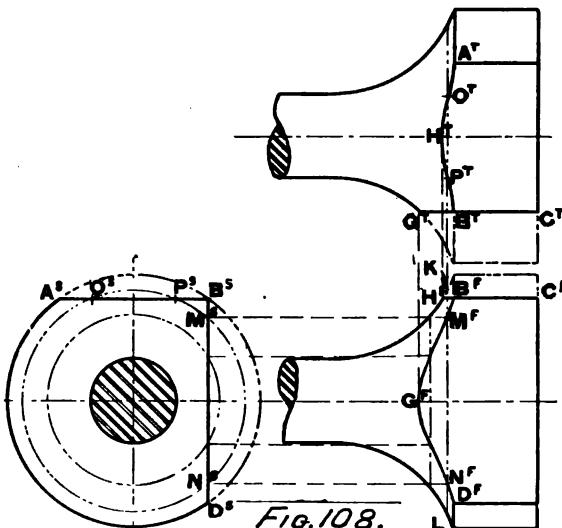
Fig.108.

would be intersected by the plane of A^SB^S and B^SD^S at the points O^S, P^S, M^S, and N^S, and hence these points will be points common to the two surfaces, and therefore points of the curves of intersection. Projecting these points on to the front and top views will determine two points in each curve. In like manner obtain other points.

Fig. 109 illustrates a practical application of the preceding principle, and is a drawing of the same stub end as that shown in Fig. 98, page 53. In any sketch of a stub end we should have such dimensions as are given in Fig. 109, but it will be seen that neither of the points H^r or G^r are given, and the position of the center X is unknown. As the curve of the bell-shaped piece is tangent to the neck of the rod, the diameter of which is given, it is only necessary to obtain one point in this curve to fix its position. This is to be determined by revolving the point B until it lies in the plane of the paper. To do this, an end view will be required; but since economy in the use of lines is advisable, let the line B^rV represent

the center line of this end view, and the rectangle B^rWYV the half-end view of the stub end. As W is the end view of the point B^r, its distance from the axis will be VW, which,
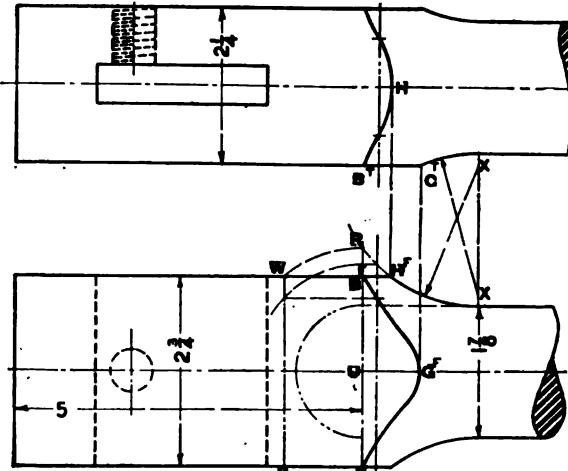
Fig. 109.

being laid off on the front view at R, determines the revolved position of B, and the required point in the curve. Through this point, and tangent to the neck of the rod,

EXAMPLE 4. CONNECTING ROD 73

with the given radius, describe the arcs representing the bell-shaped portion, observing that all of the centers must be in the same line *XX*. These arcs will determine the limiting points of the curves of intersection, and intermediate points may be found as in the preceding problem, and as illustrated in this figure.

The method of penciling one view directly over another is commonly used when the view is to serve no other purpose than that of determining lines of intersection.

Fig. 110.

Fig. 110 illustrates a case in which the cutting plane is tangent to the diameter of the cylinder. Determine the curve from the

dimensions given, using the side view only for the purpose of obtaining the curve of intersection, and in the manner illustrated in the preceding problem.

100. Example 4. Fig. 111, page 74. Assembly drawing for a Connecting Rod. The lay-out for this example has been fully considered in Art. 96, page 68. If a full-size drawing is desired, it can be obtained by using a 14″ × 20″ sheet.

Study Arts. 97 to 99, pages 69 to 73. Begin the drawing by locating all center lines, making measurements therefrom when possible. Arts. 42 and 43, page 29. Observe that the sketch for the bronze boxes has been made with the halves in their relative position, and figured from the center lines instead of the plane faces. The bearing surfaces of the larger pair of boxes has been rounded and the radius given to fit the fillet on the crank pin. In drawing the smaller, or crosshead end, see that the small end of the key projects below the bottom face of the strap an amount sufficient for the cotter pin, but allow

BRONZE BOXES

OIL HOLE

BRONZE BOXES

ONE STEEL KEY

ONE SET SCREW

ONE BOLT

ONE STEEL STRAP

ONE STEEL ROD

TWO BOLTS

FIG. III.

SKETCH FOR CONNECTING ROD

EXAMPLE 5. CONNECTING ROD   75

Two bronze boxes

One box rounded and one square

One steel Gib and Key

One Set Screw

One steel Strap

Sketch for Connecting Rod End
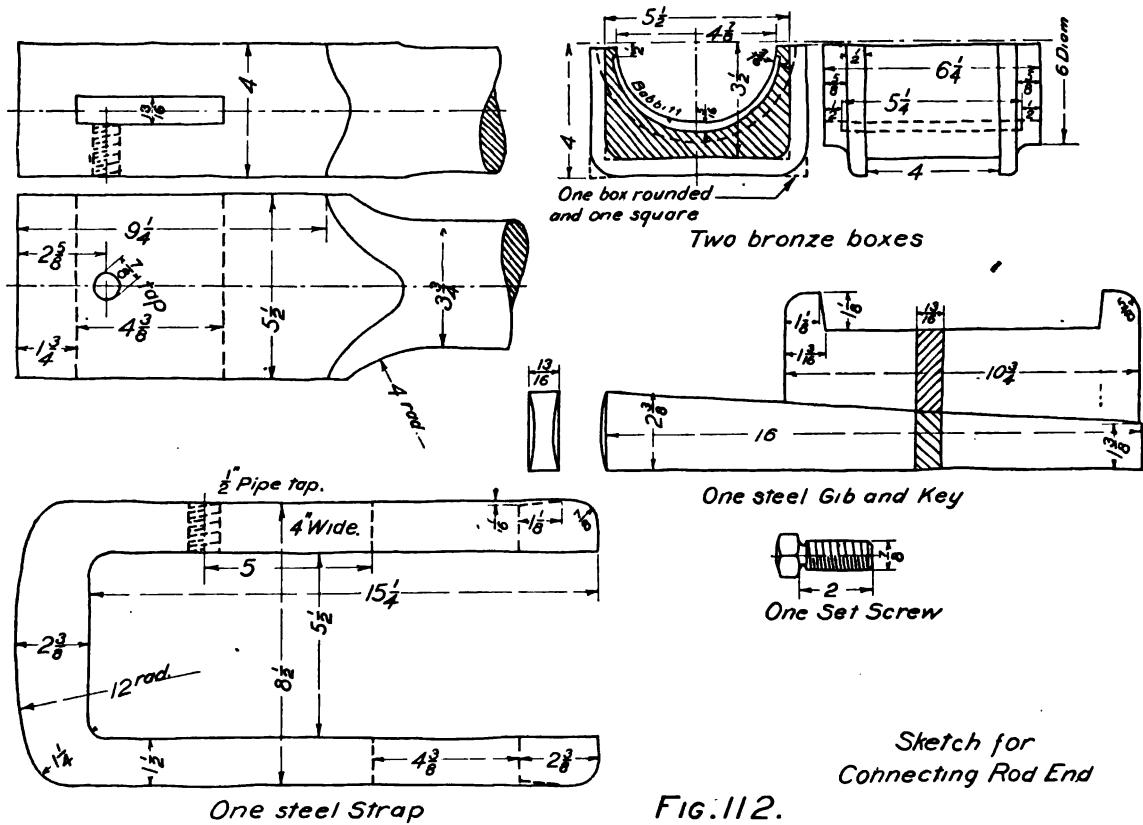
FIG.112.

no clearance.   This may slightly modify the figures for the position of the slot in the strap.   For instruction concerning the position and proportion of cotter pins in bolts and keys, see Art. 35, page 20.

Do not draw the curves of intersection on the rod until the penciling is completed. Read Art. 73, page 52, before dimensioning.*

101. **Example 5.   Fig. 112, page 75. Assembly drawing for the Crank Pin Stub End of a Connecting Rod.**   Use a 10″ × 14″ sheet and see Art. 96, page 68, for lay-out.   The representation may be similar to Fig. 98, page 53. Study Arts. 97 to 99, pages 69 to 73.   The gib and key should be drawn in the same relation to the stub end as that illustrated by Fig. 105, page 70.   Omit the determination of the curves of intersection on the rod until the penciling is completed.*   Arts. 42 and 43, page 29.

102. **Example 6.   Fig. 113, page 77. Assembly drawing for a Crosshead.**   Fig. 113 illustrates the sketches for a crosshead of very

* For purposes of instruction the dimension lines may be penciled before inking, but this is never done in practice.

simple construction designed for a 25-horsepower engine.

Two views will suffice for the representation, and the lay-out (Art. 46, page 33) may be made for a 10″ × 14″ sheet.   The end view may be drawn in full or, if not sufficiently clear, one half of it may be shown in dotted section.   It will be observed that the taper for the two ends of the crosshead pin is continuous; therefore it was necessary to give only the extreme diameters; also, that the pin is made to fit the taper hole in the crosshead.   The tapped hole in the crosshead pin is for an oiling device not shown.

103. **Example 7.   Fig. 114, page 78. Detail drawing for a Crosshead.**   The scale and the size, number, and arrangement of the sheets are left to the discretion of the student. Arts. 46 and 47, page 33.   The type here shown differs from the ordinary form of crosshead, being made in halves, the parts being united by four bolts, which also serve to clamp the piston rod to the crosshead, and to prevent any movement of the slide gibs other

EXAMPLE 6. CROSSHEAD   77

Three Cap
Screws for Washer

One cast iron Washer.   Cast iron.

3 ~ ⅝ holes

One Crosshead Pin-Steel.

¼" Pipe tap

Two Clamp Bolts.
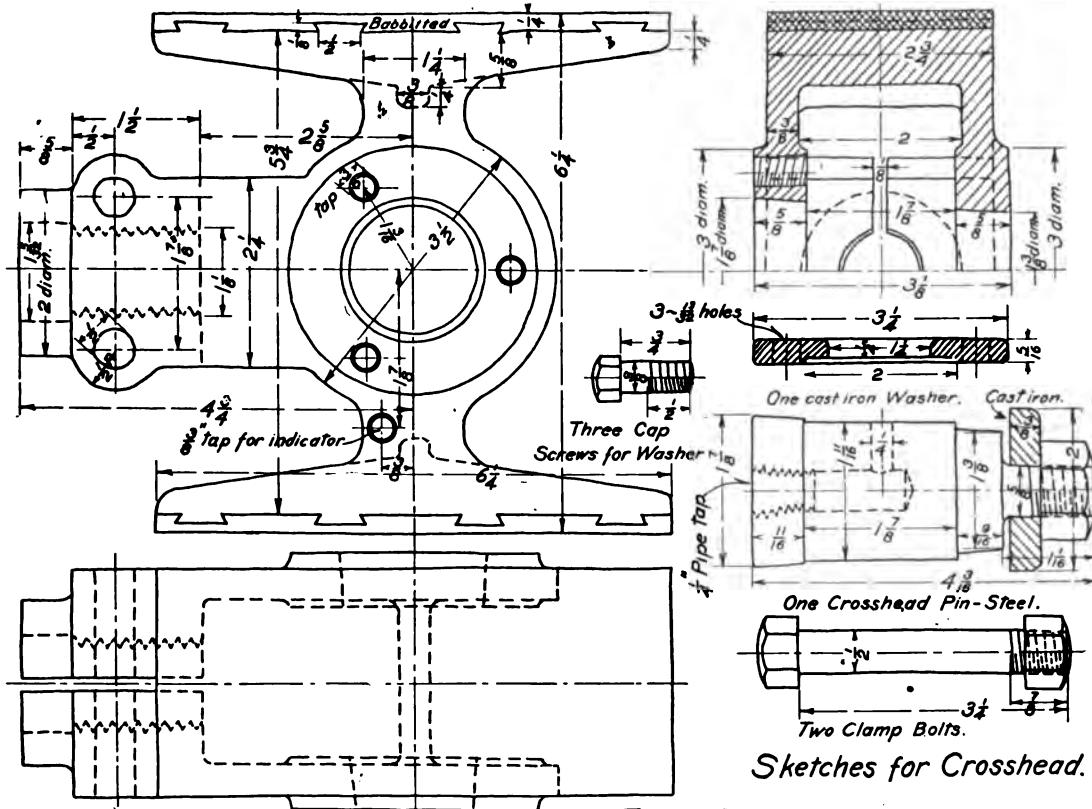
Sketches for Crosshead.

Fig. 113.

Fig. 114.

CROSSHEAD
SCALE
DATE

EXAMPLE 8. STEAM CYLINDER   79
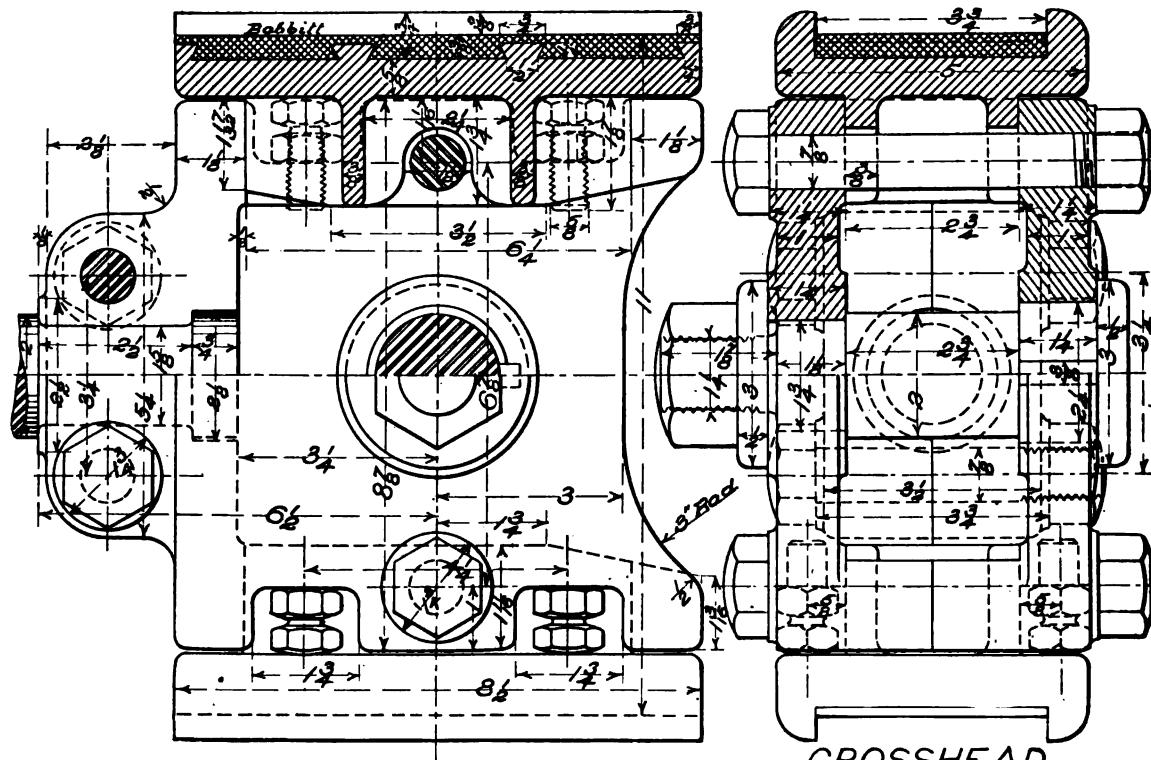
than that governed by the gib screws. Three views of one half of the main casting will be required, the only difference between the halves being in the diameter of the hole for the crosshead pin, and the key for the same. A note will suffice to explain this difference, and one of these holes may be shown in red, or in a different character of black line. Two views of the slide gib will be sufficient. The pin and screws are also to be detailed.

104. Example 8. Figs. 115 and 116, pages 80 and 81. Assembly drawing of Cylinder for a Slide Valve Engine, 15″ diameter, 14″ stroke. Make a lay-out sketch (Art. 46, page 33) for a 10″ × 14″ sheet. Art. 37, page 23.

It is required to draw two vertical sectional views of the cylinder, together with piston, piston rod, cylinder heads, stuffing boxes, valve chest cover, valve and valve rod, complete and in working condition; that is to say, with the parts in such relative position as will represent one phase during the operation of the engine. An important limiting position would be that with the piston at the extreme end of one stroke, and in this case in its nearest position to the outside cylinder head. The distance between the cylinder heads may be obtained from the drawings, and, knowing the stroke and thickness of the piston, the clearance between the piston and either cylinder head may be obtained. When the piston is in this position one piston ring should overlap that portion of the cylinder bore which is 15″ diameter.

The transverse sections should be drawn so as to show the inside of the front head. A desirable method of representing this section would be to make one half of it on a plane through the center of the cylinder, and the other half on planes passing through the steam opening and center of the foot, since it is not necessary for the plane of a section to be continuous. Art. 59, page 43. The longitudinal section should be on the plane of the center.

The valve must be shown in such position as would admit the steam to the end of the cylinder nearer the piston. The opening between the end of the valve and the port is called "lead," and in this case will be $\frac{1}{8}$″.

FIG. 115.   CYLINDER FOR 15"×14" SLIDE VALVE ENGINE.
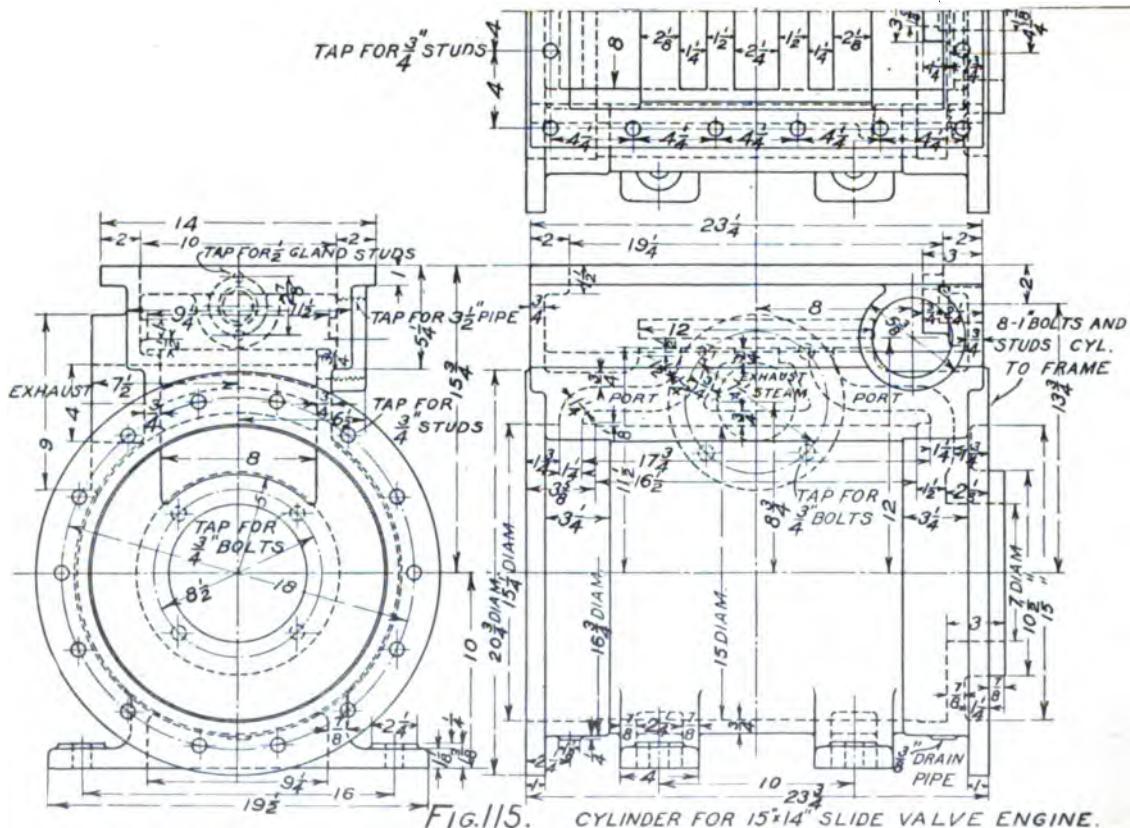
EXAMPLE 8. STEAM CYLINDER DETAILS   81
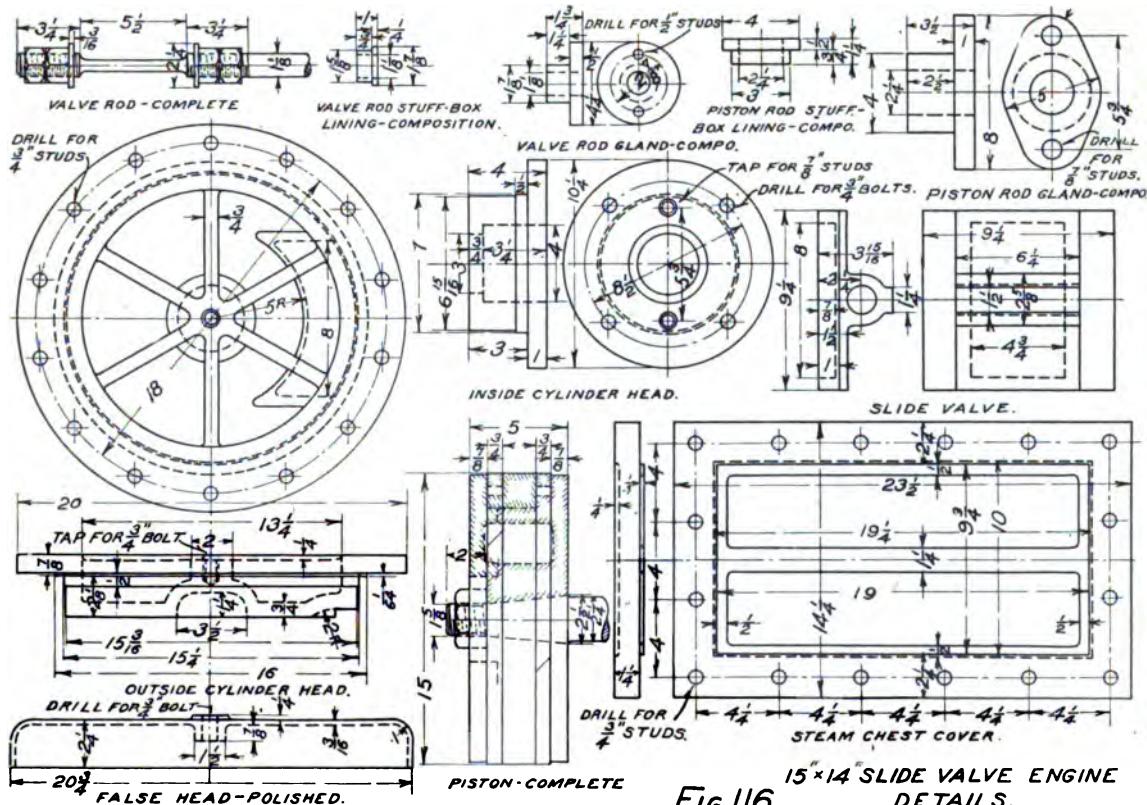
FIG. 116.

15" × 14" SLIDE VALVE ENGINE
DETAILS.

Fig. 84, page 42, and Fig. 89, page 44, suggest the treatment of details relating to the cylinder head, stuffing box, bolts, and studs. In general, show the visible parts lying beyond the plane of a section. See also Art. 57, page 40. Do not omit the lines of intersection between the ports and the bore of the cylinder and cylinder head. The piston rod and piston, valve rod, bolts and studs will not be sectioned, but other parts may be more clearly represented in section in both views.

The details of the piston, together with the names of its parts, are shown in Fig. 94, page 46. This figure should be studied previous to making its representation in the cylinder, even though the details are to be omitted from the assembly drawing. Note the method of fastening the piston to the rod, and see that sufficient clearance is provided in the cylinder head for the nut and thread of the piston rod.

As the $3\frac{1}{2}''$ steam opening would not appear on the longitudinal section, that portion of the cylinder having been removed, it may be represented by dot and dash lines, which are frequently employed for imaginary views, or parts, which have been removed. The surface for the exhaust pipe will be drilled and tapped for a standard flange. (Page 100.) The diameter, depth, and character of all holes must be clearly indicated, the necessary length of bolts and studs being determined. Art. 15, page 8.

Begin the drawing by making sections of the cylinder, after which put in other parts as though assembling the actual machine. Avoid drawing unnecessary dotted lines. Indicate the sectioned surfaces when drawing them, using the method of Fig. 81, page 39. Put no dimensions on the penciled drawings.

Observe the order for inking as given in Art. 43, page 29, and ink no section lines until after the drawing is dimensioned.

In general, dimension the drawing for finished surfaces only, but add such other dimensions as appear useful for general reference. Art. 66, page 47. Art. 67, page 49. Art. 70, page 50. Art. 72, page 51.

The drawing should be checked with great care when completed. Arts. 80 and 81, page 57.

105. **Example 9. Fig. 117, page 84. Assembly drawing for a Pillow Block Bearing,** designed for an $18'' \times 36''$ stationary engine, the diameter of the journal being $15''$.

Two views will suffice for the representation, and they may include the necessary sections. Make a lay-out sketch (Art. 46, page 33) for a $10'' \times 14''$ sheet. Art. 37, page 23.

Note the clearance between the upper shell and side shells which is provided for taking up the wear of the journal. This space is frequently filled by a piece of metal known as a "shim." The shells are lined with Babbitt metal, which should be shown in one of the sectional views.

Some unimportant radii of curvature, not easily obtainable from the casting, were omitted and must be supplied by the draftsman. Do not obliterate these centers when cleaning the drawing, as they may serve subsequent workmen. See Art. 43, page 30, last paragraph.

Make the tapped holes for the cap screws of sufficient depth to allow for taking up the wear in the shells besides providing for the ordinary clearance. Art. 15, page 8.

106. **Example 10. Fig. 118, page 85. Detail of the base for a Back Rest.** Two views of the back rest for a milling machine are given, and it is required to draw the detail of the base, illustrating it by three views. This example was chosen to show the use of a dotted section (Art. 55, page 38) and the advantages to be derived from the omission of shade lines on cylindrical surfaces. Without the use of these systems it would be very difficult to show all of the details by two views. The only detail which has been omitted is that of the clearance curve cut from the base for the adjusting nut. In the front view this nut is shown in full section, save where it is concealed by the casting. The dotted section of the side view is that made by a plane through the center of the slide.

A $10'' \times 14''$ sheet will suffice for a full scale drawing of the three views.

One Main Casting

Top Shell
Bottom Shell

Top Shell
Bottom Shell

One Top and one bottom shell.
Cast Iron and Babbitted.

Two Side Shells.
Cast Iron and Babbitted.

One Grease Cup Cap.

4 Thrust Screws
Steel

2 Cap Screws
Steel.

One Pillow Block Cap

Center line of Shaft
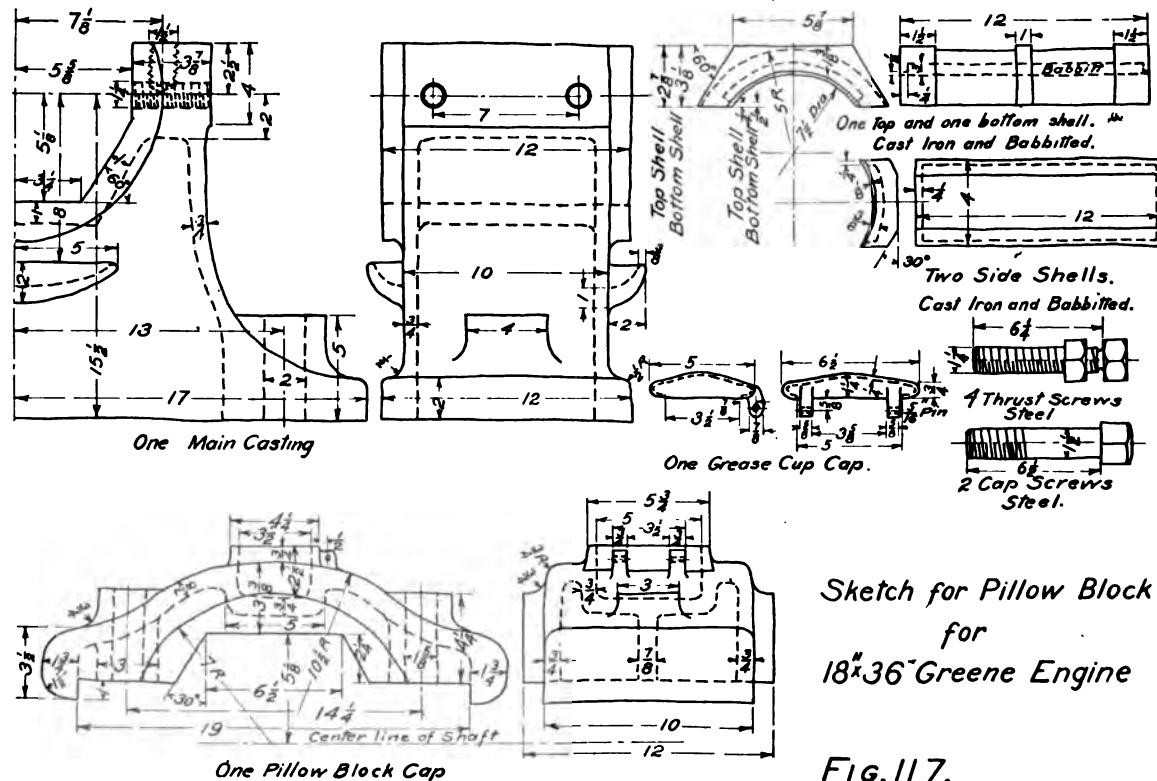
Sketch for Pillow Block
for
18"x36" Greene Engine

Fig. 117.

EXAMPLE 10. BACK REST 85
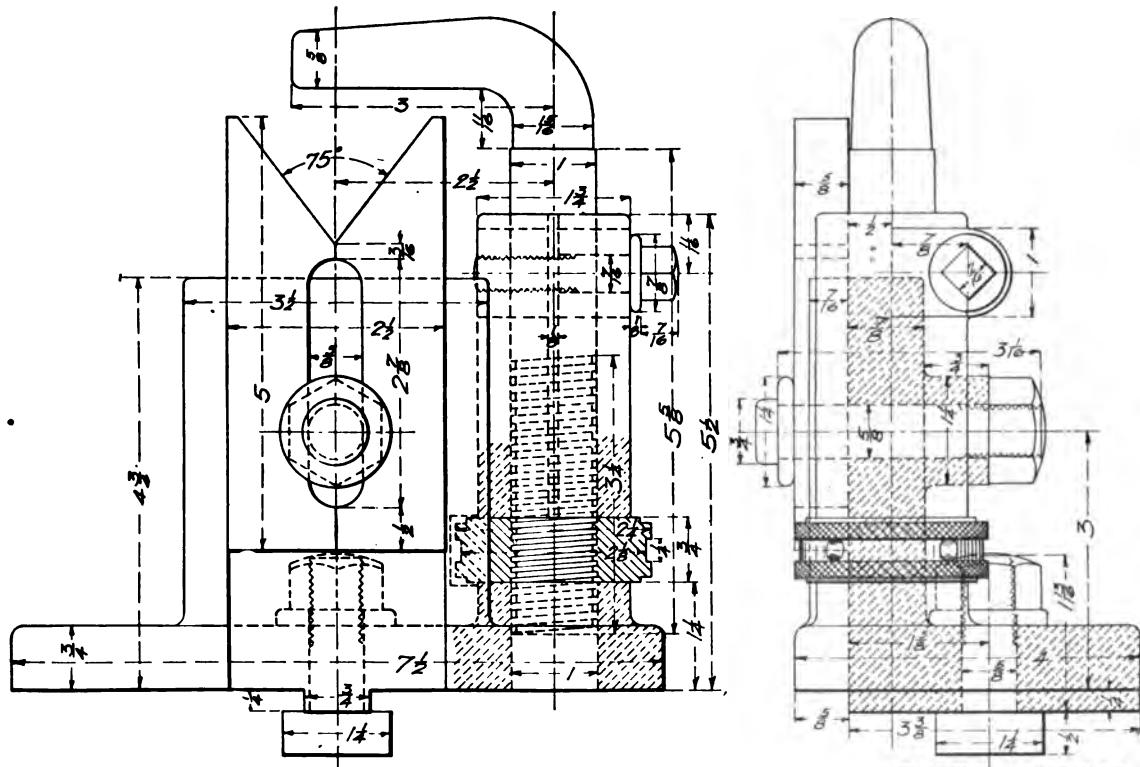
Fig. 118.

BACK REST

SCALE:
DATE:

ONE HEAD

TWO BEARING NUTS

ONE BEARING NUT   FIG. 119.

ONE DRIVING PULLEY

ONE LOOSE PULLEY

SCREW POLISHING
MACHINE
CAST IRON DETAILS
SCALE
DATE

EXAMPLE 11. SCREW POLISHING MACHINE 87

ONE TAIL SCREW

ONE REAR BEARING.

ONE FRONT BEARING.

ONE WASHER

ONE SPRING No. 17 WIRE.

TWO CAPS.

ONE NUT SCREW.

ONE CENTER DRIVE.

ONE CENTER.

ONE DRIVING PULLEY   ONE LOOSE PULLEY
SCREW   SCREW.

ONE SPINDLE.

SCREW POLISHING MACHINE
STEEL FORGING DETAILS.
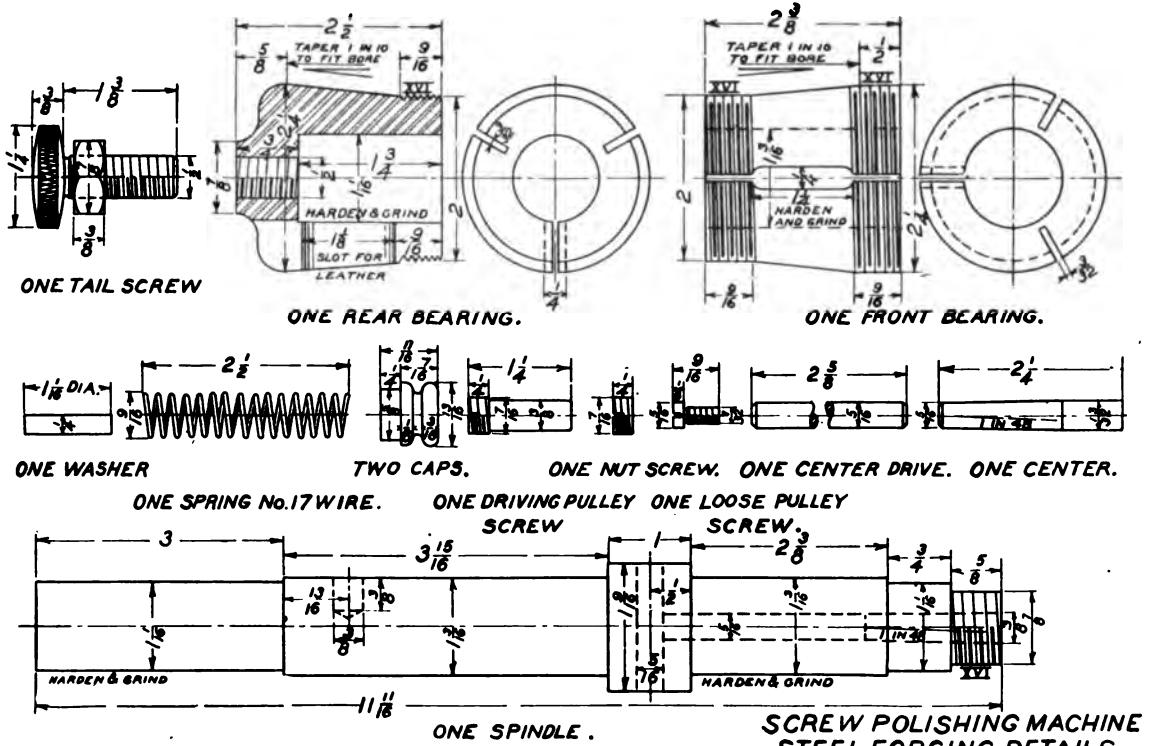
SCALE
DATE

FIG. 120.

107. Example 11. Figs. 119 and 120, pages 86 and 87. Assembly drawing for a Screw Polishing Machine. One view is sufficient for the representation of all save the main casting, and as this drawing is not for the pattern maker, the end view is unnecessary.
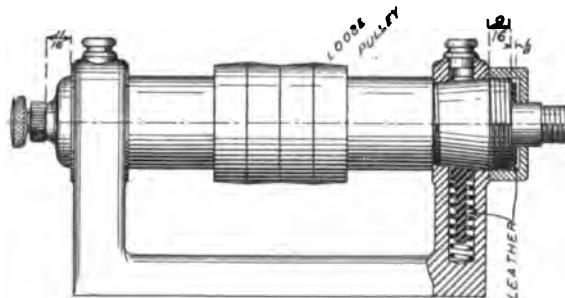
Fig. 121.

Nearly all of the parts will be shown in section, but some of the minor details, such as the bearing slots, oiling device, and leather washer, may require explanatory notes. Observe that the spring shown in Fig. 121 is that detailed on Fig. 120, but must be shown as compressed when drawn in its proper relation to the other parts. After having determined the lay-out, Art. 46, page 33, begin the drawing by locating the center line, and position of bearings with relation to the casting, as given in Fig. 121. Then, without completing any of the details, determine the position of pulleys, collar, tail screw, etc. Be sure that proper provision has been made for taking up the wear of the boxes. In order to avoid confusion it is well to indicate the different pieces by sectioning them in pencil, as in Fig. 81, page 39.

108. Example 12. Figs. 122 and 123, pages 90 and 91. Detail drawing for the Tail Stock of a 17″ Lathe. Two drawings would be required for these details, one for the castings and one for the forgings. The latter is the more valuable study and will necessitate a careful reading of the entire drawing.

The lay-out sheet for the forgings will require much attention, but with proper care it is possible to make a full-size drawing of all the parts on a 10″ × 14″ sheet. The following suggestions will assist the student in making the lay-out sketch. Arrange the de-

EXAMPLE 13. LATHE HEAD STOCK   89

tails in five horizontal lines as follows: First line: the Eccentric Clamp Shaft, shown in the section on *ABCD*, Fig. 122, page 90. Draw two views. Second line: the Spindle, and the Hand Wheel Handle. The Spindle will have to be broken between the taper for the center and the brass nut, which latter need not be drawn. Third line: the Center and Tail Screw. Make the former to fit the taper in the spindle. Art. 68, page 49. The Tail Screw will have to be broken in the thread, which is left-hand and square. Fourth line: the Side Screw and Spindle Clamp Screw. The former is clearly shown in the section on *EF*, but the diameters of the collar on the right-hand end, and the washer on the left, are not given, these being left for the student to determine. Observe that these parts must clear the lower casting. The Side Screw must be broken in the thread. The Spindle Clamp Screw is well shown in the section on *ABCD*. Fifth line: the Clamp Screw, Shelf Screws, Spindle Nut Screw, and Spindle Key. Also leave space for title.

See that all parts are completely and correctly represented and figured; that the number of each piece and the character of the metal be specified; and finally, make sure of the accuracy of all by a careful examination of every detail, and by checking the drawing. Arts. 80 and 81, page 57.

109. **Example 13. Figs. 125, 126, and 127, pages 94, 95, and 96. Assembly drawing for a 16″ Lathe Head Stock.** The representation on the drawing will be that shown by Fig. 124, save that it must be more complete, involving the use of much sectioning. The scale should not be less than half size, and full size would be better if it did not necessitate a very large sheet and the possible separation of the front and side views, each requiring a sheet.

The sketches have not been drawn to scale, although the proportion of the various parts have been preserved where practicable. Small parts have been necessarily enlarged, in order to make the sketch legible. Fig. 125 includes the main casting, together with the boxes and shafts. The cone and conehead are also

SECTION ON E.F.

SECTION ON A.B.C.D.

FIG.122.

EXAMPLE 12. LATHE TAIL STOCK 91

FIG. 123.

17" LATHE
TAIL STOCK
SCALE:
DATE
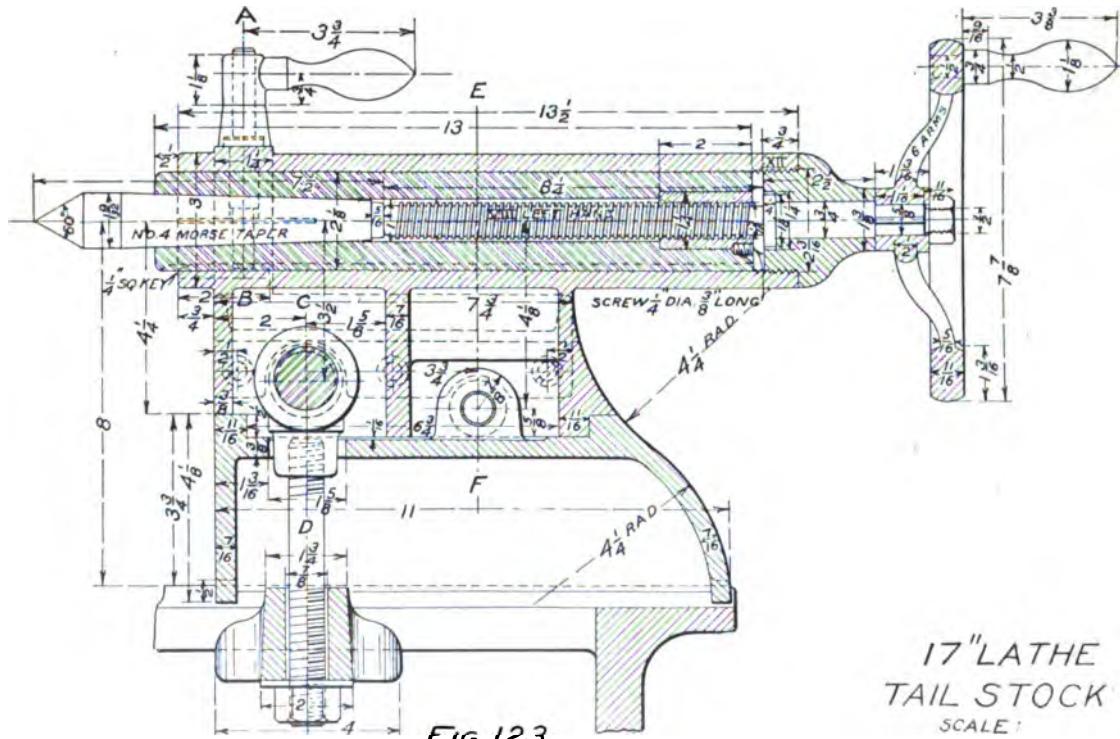
shown there.   Fig. 126 illustrates the small castings and brass details with a few accompanying forgings.   Fig. 127 is a sketch of the forgings and gears.

By reference to Fig. 124, it will be observed that in the main view, the upper shaft, called the quill, is a revolved position of that shaft, the center of which is shown on the side view at *A*.   If an attempt had been made to draw this in its proper position behind the main casting, it would have resulted in confusion, and would have required another view to illustrate the simple details shown in the figure. This method of illustrating a train of gears,

Fig. 124.

EXAMPLE 13. LATHE HEAD STOCK   93
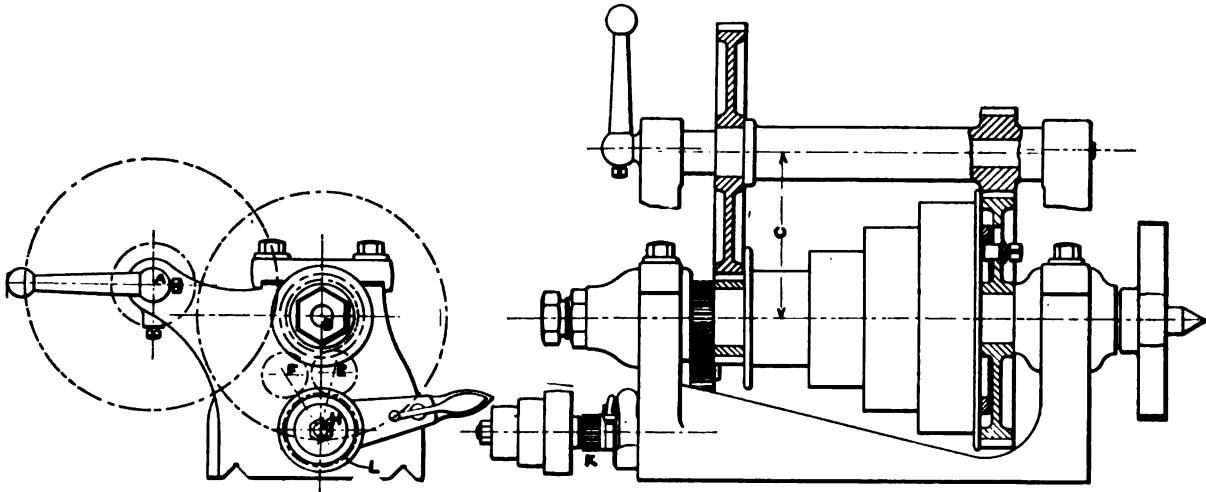
as though their shafts were all in one plane, is an excellent device for detailing a system of gearing, showing the gears, shafts, distance between centers, and the actual or relative velocity of the several shafts. In connection with this, an end view should be shown, with the centers of the shafts in their relative positions, and the pitch lines of the gears also drawn. When such a representation is made of several trains of mechanism operated by a single driving shaft, but performing different functions, the pitch lines of the different trains may to advantage be represented in different colors. Referring again to Fig. 124, it will be seen that the gears shown in the front view are in working contact, the distance between their centers, C, being equal to one half the sum of their pitch diameters. But in the side view, these same gears are not drawn in contact, but in their extreme position to the left. This lateral movement of the back gear is accomplished by means of an eccentric quill shaft, as may be seen on Fig. 127. The intermediate gears, EF, are for changing the direction

of the motion transmitted through the change gear marked K, to the screw operating the carriage of the lathe, but not shown in the figure. The centers B, E, and H do not lie in the same plane; and since it would be desirable to represent them in the same sectional plane, when drawing the front view, it will be necessary to draw the shaft, having its center at H, at a different height in the front view, which would be rather objectionable, or to so change the diameters of gears E and H that the gear E could be shown in the plane of the other two. The error in the drawing made by using this latter method, which is the better of the two, will not be perceptible.

In the sketches of the gears * the outside diameters and number of teeth are given, but the pitch and the pitch diameters must be figured. If N equals the number of teeth, D the outside diameter, P the pitch, and D' the pitch diameter, $P = \dfrac{N+2}{D}$, and $D' = \dfrac{N}{P}$.

* The student is referred to the "Essentials of Gearing" of this series for the theory and practice of gear drafting.

Head-Cast Iron

Cone Pulley - Cast Iron

Cone Head-Cast Iron

Two Boxes-Brass

Two Boxes - Brass

Two Caps-Cast Iron

Oil Pipe - Brass
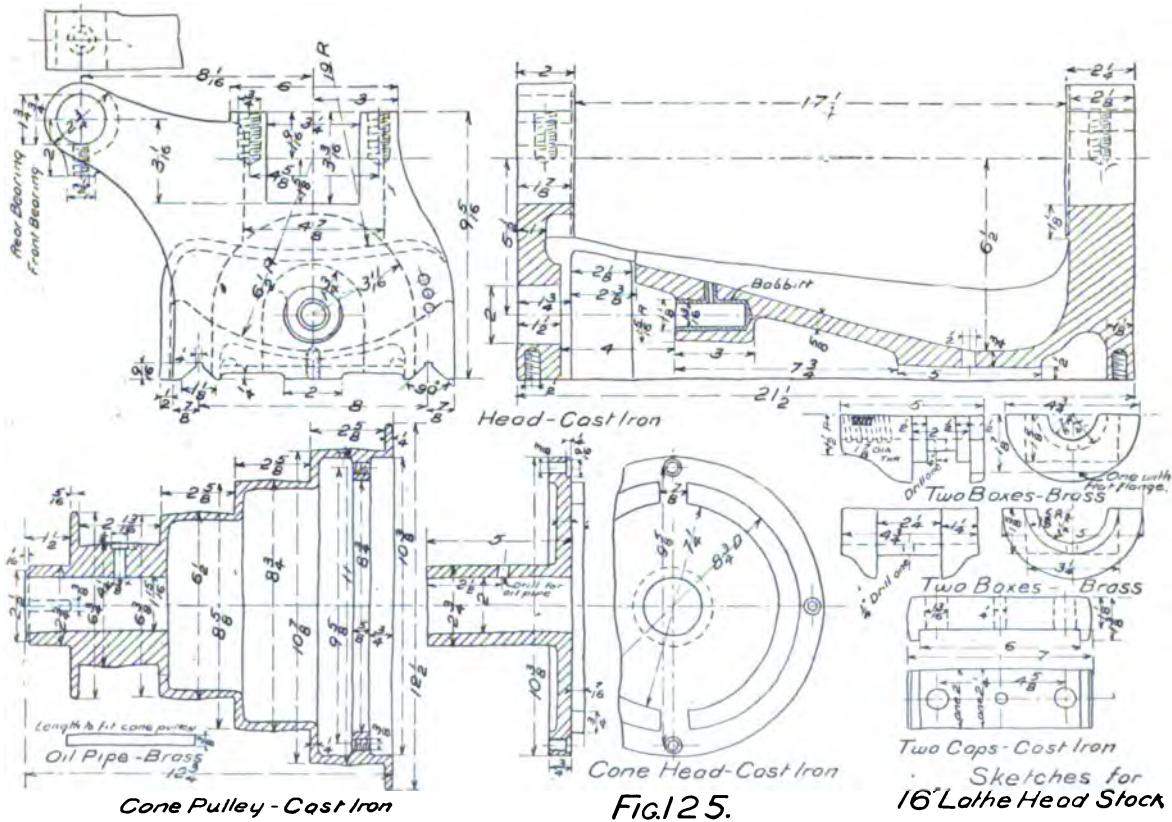
Sketches for
16"Lathe Head Stock

FIG.125.

EXAMPLE 13. LATHE HEAD STOCK   95

Intermediate Gear Bushing - Cast Iron

Feed Cone - Cast Iron

Quill Shaft Bushing - Cast Iron

Spindle Thrust Screw-Steel

Thrust Washer Brass

Lock Pin Fulcrum Steel

Feed Lever - Cast Iron

Face Plate - Cast Iron

Quill Shaft Handle - Steel

Lock Pin Handle - Brass

Lock Pin - Steel

Lock Pin Spring Steel

Sketches for 16" Lathe Head Stock
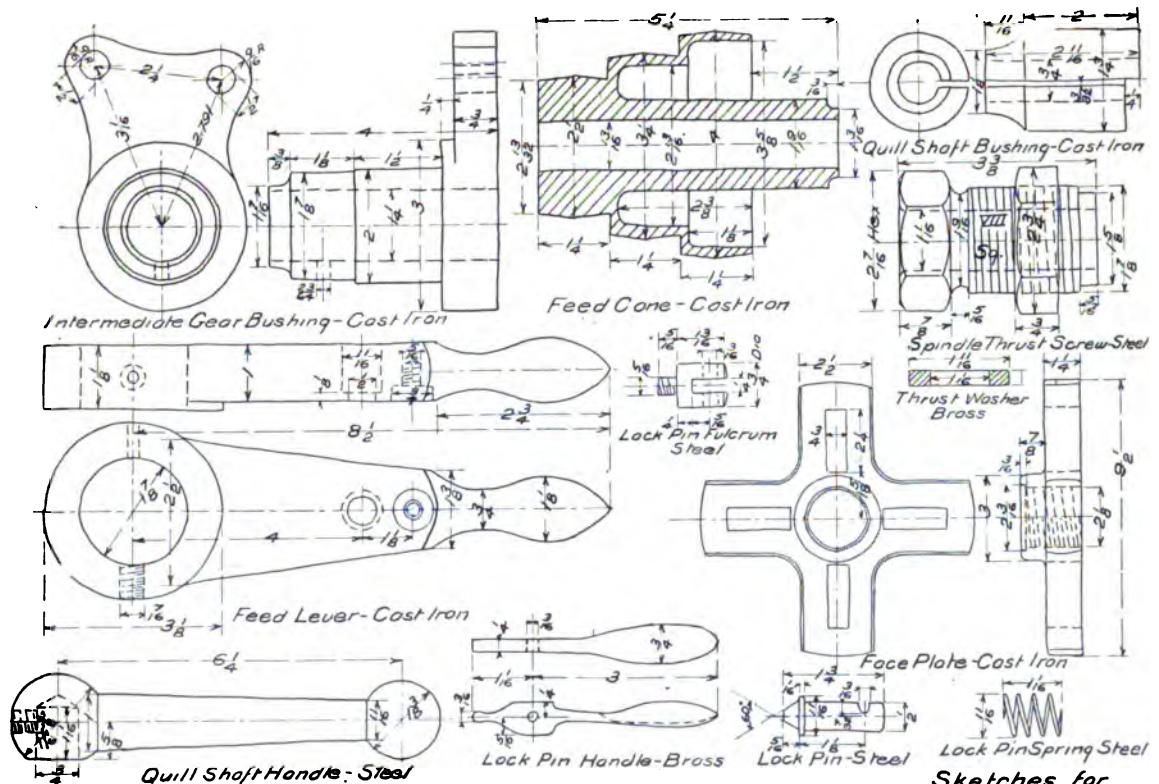
Fig. 126.

Sketches for
16" Lathe Head Stock
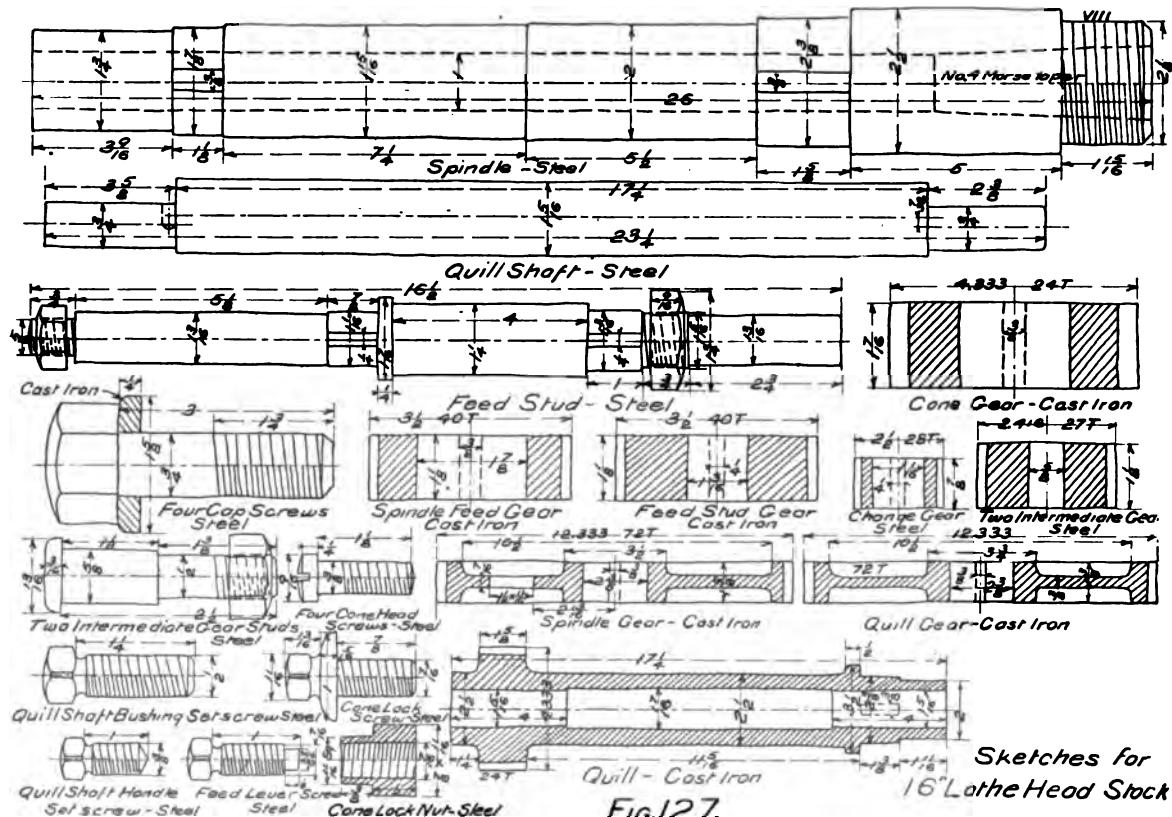
FIG.127.

TABLES

BRIGGS' STANDARD PIPE DIMENSIONS.

A = IMPERF. TOP & BOTTOM 2 THDS.
B = FLAT TOP IMPERF. " 4 "
C = PERFECT THREADS.

$\frac{1}{32}$" IN 1" OF LENGTH
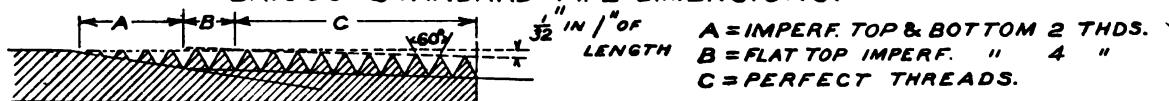
NOMINAL INSIDE DIAM.	ACTUAL INSIDE DIAM.	ACTUAL OUTSIDE DIAM.	THICKNESS OF METAL	NO. THREADS PER INCH.	NO. PERFECT THREADS	DISTANCE PIPE ENTERS	DIAM. OF TAP DRILL.
$\frac{1}{8}$	.270	.405	.068	27	5.13	.19	$\frac{21}{64}$
$\frac{1}{4}$	.364	.540	.088	18	5.22	.29	$\frac{27}{64}$
$\frac{3}{8}$	.494	.675	.091	18	5.4	.30	$\frac{9}{16}$
$\frac{1}{2}$	.623	.840	.109	14	5.46	.39	$\frac{11}{16}$
$\frac{3}{4}$	.824	1.050	.113	14	5.6	.40	$\frac{29}{32}$
1	1.048	1.315	.134	$11\frac{1}{2}$	5.87	.51	$1\frac{1}{8}$
$1\frac{1}{4}$	1.380	1.660	.140	$11\frac{1}{2}$	6.21	.54	$1\frac{15}{32}$
$1\frac{1}{2}$	1.610	1.900	.145	$11\frac{1}{2}$	6.33	.55	$1\frac{23}{32}$
2	2.067	2.375	.154	$11\frac{1}{2}$	6.67	.58	$2\frac{3}{16}$
$2\frac{1}{2}$	2.468	2.875	.204	8	7.12	.89	$2\frac{9}{16}$
3	3.067	3.500	.217	8	7.6	.95	$3\frac{3}{16}$
$3\frac{1}{2}$	3.548	4.000	.226	8	8.0	1.00	$3\frac{11}{16}$
4	4.026	4.500	.237	8	8.4	1.05	$4\frac{3}{16}$
$4\frac{1}{2}$	4.508	5.000	.246	8	8.8	1.10	
5	5.045	5.563	.259	8	9.28	1.16	
6	6.065	6.625	.280	8	10.08	1.26	
7	7.023	7.625	.301	8	10.88	1.36	
8	7.982	8.625	.322	8	11.68	1.46	
9	9.000	9.625	.344	8	12.56	1.57	
10	10.019	10.750	.366	8	13.44	1.68	

PIPE FITTINGS.*   STANDARD PIPE FLANGES.
Letters refer to opposite page.

DIA. OF PIPE	A	B	C	D	E	F	G	DIA. OF PIPE	DIA. OF FLANGE	THICKNESS OF FLANGE	DIA. OF BOLT CIRCLE	BOLTS NO.	DIA.	LENGTH
$\frac{1}{4}$	$\frac{3}{4}$	$1\frac{1}{8}$	$1\frac{1}{8}$	1	$\frac{7}{16}$		$1\frac{23}{32}$	1	4	$\frac{7}{16}$	3	4	$\frac{7}{16}$	$1\frac{1}{2}$
$\frac{3}{8}$	$\frac{27}{32}$	$1\frac{11}{16}$	$1\frac{11}{16}$	1	$\frac{9}{16}$		$1\frac{13}{16}$	$1\frac{1}{4}$	$4\frac{5}{8}$	$\frac{1}{2}$	$3\frac{3}{8}$	4	$\frac{7}{16}$	$1\frac{1}{2}$
$\frac{1}{2}$	$1\frac{5}{32}$	$2\frac{3}{16}$	$2\frac{3}{16}$	$1\frac{1}{4}$	$\frac{11}{16}$	$1\frac{1}{4}$	$2\frac{1}{16}$	$1\frac{1}{2}$	5	$\frac{9}{16}$	$3\frac{7}{8}$	4	$\frac{1}{2}$	$1\frac{3}{4}$
$\frac{3}{4}$	$1\frac{5}{16}$	$2\frac{5}{8}$	$2\frac{5}{8}$	$1\frac{5}{8}$	$\frac{13}{16}$	$1\frac{1}{4}$	$2\frac{7}{32}$	2	6	$\frac{5}{8}$	$4\frac{3}{4}$	4	$\frac{5}{8}$	2
1	$1\frac{17}{32}$	$3\frac{1}{16}$	$3\frac{1}{16}$	$1\frac{7}{8}$	$\frac{15}{16}$	$1\frac{3}{8}$	$2\frac{8}{32}$	$2\frac{1}{2}$	7	$\frac{11}{16}$	$5\frac{1}{2}$	4	$\frac{5}{8}$	$2\frac{1}{4}$
$1\frac{1}{4}$	$1\frac{13}{16}$	$3\frac{5}{8}$	$3\frac{5}{8}$	$2\frac{1}{8}$	$1\frac{1}{16}$	2	$2\frac{5}{8}$	3	$7\frac{1}{2}$	$\frac{3}{4}$	6	4	$\frac{5}{8}$	$2\frac{1}{8}$
$1\frac{1}{2}$	2	4	4	$2\frac{3}{8}$	$1\frac{3}{16}$	2	$2\frac{27}{32}$	$3\frac{1}{2}$	$8\frac{1}{4}$	$\frac{13}{16}$	7	4	$\frac{5}{8}$	$2\frac{1}{8}$
2	$2\frac{3}{8}$	$4\frac{3}{4}$	$4\frac{3}{4}$	$2\frac{5}{8}$	$1\frac{3}{8}$	$2\frac{1}{16}$	$2\frac{30}{32}$	4	9	$\frac{15}{16}$	$7\frac{1}{2}$	4	$\frac{3}{4}$	$2\frac{3}{4}$
$2\frac{1}{2}$	$2\frac{7}{8}$	$5\frac{1}{4}$	$5\frac{1}{4}$	$2\frac{7}{8}$	$1\frac{5}{8}$	$2\frac{1}{16}$	$3\frac{3}{8}$	$4\frac{1}{2}$	$9\frac{1}{4}$	$\frac{15}{16}$	$7\frac{3}{4}$	8	$\frac{3}{4}$	3
3	$3\frac{5}{16}$	$6\frac{5}{8}$	$6\frac{5}{8}$	$3\frac{1}{2}$	$1\frac{7}{8}$	$2\frac{5}{8}$	$3\frac{11}{16}$	5	10	$\frac{15}{16}$	$8\frac{1}{2}$	8	$\frac{3}{4}$	3
$3\frac{1}{2}$	$3\frac{21}{32}$	$7\frac{1}{4}$	$7\frac{3}{8}$	$3\frac{3}{4}$	$2\frac{1}{16}$	$2\frac{11}{16}$	$4\frac{5}{16}$	6	11	1	$9\frac{1}{2}$	8	$\frac{3}{4}$	3
4	$4\frac{1}{16}$	$8\frac{1}{16}$	$8\frac{1}{16}$	$3\frac{3}{4}$	$2\frac{1}{4}$	$3\frac{1}{8}$	$4\frac{3}{4}$	7	$12\frac{1}{2}$	$1\frac{1}{8}$	$10\frac{1}{4}$	8	$\frac{3}{4}$	$3\frac{1}{4}$
$4\frac{1}{2}$	$4\frac{13}{32}$	$8\frac{13}{16}$	$8\frac{11}{16}$	$3\frac{3}{4}$	$2\frac{7}{8}$	$3\frac{3}{8}$		8	$13\frac{1}{2}$	$1\frac{1}{8}$	$11\frac{3}{4}$	8	$\frac{3}{4}$	$3\frac{1}{2}$
5	$4\frac{21}{32}$	$9\frac{1}{4}$	$9\frac{5}{16}$	4	$2\frac{3}{8}$	$3\frac{1}{2}$		9	15	$1\frac{1}{8}$	$13\frac{1}{4}$	12	$\frac{7}{8}$	$3\frac{1}{2}$
6	$5\frac{7}{16}$	$10\frac{5}{8}$	$10\frac{5}{8}$	$4\frac{1}{2}$	$2\frac{13}{16}$	$3\frac{5}{8}$		10	16	$1\frac{3}{16}$	$14\frac{1}{4}$	12	$\frac{7}{8}$	$3\frac{5}{8}$
7	$6\frac{1}{16}$	$12\frac{1}{8}$	$12\frac{1}{8}$	$4\frac{1}{4}$	$3\frac{5}{8}$	$3\frac{3}{4}$		12	19	$1\frac{1}{4}$	17	12	$\frac{7}{8}$	$3\frac{3}{4}$
8	$6\frac{13}{16}$	$13\frac{5}{8}$	$13\frac{5}{8}$	$4\frac{1}{2}$	$3\frac{5}{8}$	$3\frac{3}{4}$		14	21	$1\frac{3}{8}$	$18\frac{3}{4}$	12	1	$4\frac{1}{4}$
9	$7\frac{1}{2}$	15	15	$5\frac{1}{4}$	$3\frac{5}{8}$	$3\frac{7}{8}$		15	$22\frac{1}{4}$	$1\frac{3}{8}$	20	16	1	$4\frac{1}{4}$
10	$8\frac{1}{4}$	$16\frac{1}{4}$	$16\frac{1}{2}$	6	$4\frac{1}{16}$	$3\frac{1}{4}$		16	$23\frac{7}{8}$	$1\frac{7}{16}$	$21\frac{1}{4}$	16	1	$4\frac{3}{4}$
12	$9\frac{3}{8}$	$19\frac{5}{8}$	$19\frac{5}{8}$	6	$4\frac{5}{8}$	$3\frac{1}{2}$		18	25	$1\frac{5}{8}$	$22\frac{3}{4}$	16	$1\frac{1}{8}$	$4\frac{3}{4}$

*Walworth Mfg Co.

2" R & L Coupling   ⊢D⊣   ⊢A⊣

2"×1½"Reducing   ⊢D⊣   2"Coupling   2"Union   2"Flange Coupling   2"×2"Elbow
Coupling   ⊢G⊣   ⊢F⊣

2"×2"×2"Side Outlet Elbow   2"×2"×1½"Tee   2"×2"×2"Tee   2"×2"×2"×2"
                                                                 Cross
2"Plug   2"pipe   2"pipe   C
                                                      2"   2"×1½"Reducing
          2"×4"Space   1½"pipe   Bushing
          Nipple
                                                                 2"-45°Elbow
                            1½"Cap   Pipe Flange
                                      2"Space Nipple   See table opposite
2"Angle Valve

       2"Check Valve   2"Globe   2"-Y
2"Pipe Nut   Valve   2"Plug

                                                             PIPE
          Letters refer to table opposite   FITTINGS.

STANDARD TAPERS.

BROWN & SHARPE.				MORSE				F.E. REED LATHE CENTERS		
NO.	D	A	P	NO.	D	A	P	SIZE OF LATHE	D	P
1	.20	.2375	$\frac{15}{16}$	0	.252	.356	2	12	$\frac{9}{16}$	$3\frac{5}{8}$
2	.25	.2991	$1\frac{3}{16}$	1	.369	.475	$2\frac{1}{8}$	14	$\frac{15}{16}$	$4\frac{1}{8}$
3	.312	.3952	2	2	.572	.7	$2\frac{9}{16}$	16	$1\frac{1}{4}$	$4\frac{1}{8}$
4	.35	.4020	$1\frac{1}{4}$	3	.778	.938	$3\frac{3}{16}$	18	$1\frac{1}{4}$	$5\frac{1}{16}$
5	.45	.5229	$1\frac{3}{4}$	4	1.02	1.231	$4\frac{1}{16}$	20	$1\frac{1}{2}$	$5\frac{5}{16}$
6	.50	.5989	$2\frac{3}{8}$	5	1.475	1.748	$5\frac{3}{16}$	22	$1\frac{1}{2}$	$5\frac{5}{16}$
7	.60	.7250	3	6	2.116	2.494	$7\frac{1}{4}$	24	$1\frac{3}{4}$	$5\frac{1}{2}$
8	.75	.8985	$3\frac{9}{16}$	7	2.75	3.27	10	27	$1\frac{3}{4}$	$5\frac{1}{2}$
9	.90	1.0667	4	JARNO TAPER				REED TAPER		
10	1.0446	1.2888	$5\frac{11}{16}$	TAPER PER FOOT=0.6 INCH				TAPER PER FOOT=0.6INCH		
11	1.25	1.5312	$6\frac{3}{4}$	" " INCH=.05 "				" " INCH = .05 "		
12	1.50	1.7968	$7\frac{1}{8}$	$D = \dfrac{\text{NO. OF TAPER}}{10}$						
13	1.75	2.0521	$7\frac{3}{4}$	$A = \dfrac{\text{NO. OF TAPER}}{8}$						
14	2.	2.3038	$8\frac{1}{4}$	$P = \dfrac{\text{NO OF TAPER}}{2}$						
15	2.25	2.5846	$8\frac{3}{4}$							
16	2.50	2.8855	$9\frac{1}{4}$							

WOODRUFF

KEYS

Saddle Key   Flat Key   Sunk Key

No.	A	B	C	D	E
1	1/16			1/32	
2	3/32	1/2	1/2	3/64	3/64
3	1/8			1/16	
4	3/32			3/64	
5	1/8	5/8	5/8	1/16	1/16
6	5/32			5/64	
7	1/8			1/16	
8	5/32	3/4	3/4	5/64	1/16
9	3/16			3/32	
10	5/32			5/64	
11	3/16	7/8	7/8	3/32	1/16
12	7/32			7/64	
A	1/4			1/8	
13	3/16			3/32	
14	7/32	1	1	7/64	1/16
15	1/4			1/8	
B	5/16			5/32	
16	3/16			3/32	
17	7/32	1 1/8	1 1/8	7/64	5/64
18	1/4			1/8	
C	5/16			5/32	

No.	A	B	C	D	E
19	3/16			3/32	
20	7/32			7/64	
21	1/4	1 1/4	1 1/4	1/8	5/64
D	5/16			5/32	
E	3/8			3/16	
22	1/4			1/8	
23	5/16	1 3/8	1 3/8	5/32	3/32
F	3/8			3/16	
24	1/4			1/8	
25	5/16	1 1/2	1 1/2	5/32	7/64
G	3/8			3/16	
26	3/16			3/32	
27	1/4	1 23/32	2 1/8	1/8	17/32
28	5/16			5/32	
29	3/8			3/16	
R	1/4			1/8	
S	5/16			5/32	
T	3/8	2 5/16	2 3/4	3/16	5/8
U	7/16			7/32	
V	1/2			1/4	
30	3/8	2 7/8	3 1/2	3/16	13/16

Plain Key   Gib Key

U.S. NAVY
STANDARD

Diameter of Shaft in Inches
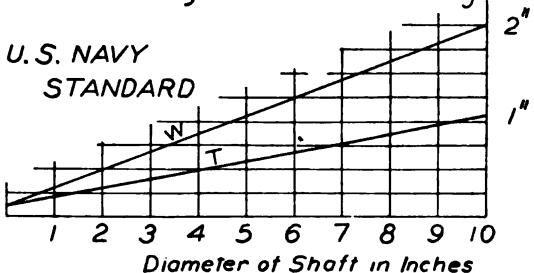
COMMON RULE.

W = diameter of shaft $\div$ 4.

T = " " " $\div$ 6

Taper of key $\frac{1}{8}$" per foot of length.

TABLES

DECIMAL EQUIVALENTS

FRACTION	DECIMAL	FRACTION	DECIMAL	FRACTION	DECIMAL	FRACTION	DECIMAL
$\frac{1}{64}$	.015625	$\frac{17}{64}$	.265625	$\frac{33}{64}$	.515625	$\frac{49}{64}$	.765625
$\frac{1}{32}$	.03125	$\frac{9}{32}$	.28125	$\frac{17}{32}$	.53125	$\frac{25}{32}$	.78125
$\frac{3}{64}$	.046875	$\frac{19}{64}$	.296875	$\frac{35}{64}$	.546875	$\frac{51}{64}$	.796875
$\frac{1}{16}$	.0625	$\frac{5}{16}$	.3125	$\frac{9}{16}$	.5625	$\frac{13}{16}$	.8125
$\frac{5}{64}$	.078125	$\frac{21}{64}$	.328125	$\frac{37}{64}$	.578125	$\frac{53}{64}$	828125
$\frac{3}{32}$	.09375	$\frac{11}{32}$	.34375	$\frac{19}{32}$	.59375	$\frac{27}{32}$	.84375
$\frac{7}{64}$	.109375	$\frac{23}{64}$	.359375	$\frac{39}{64}$	.609375	$\frac{55}{64}$	.859375
$\frac{1}{8}$	.125	$\frac{3}{8}$	.375	$\frac{5}{8}$	.625	$\frac{7}{8}$	.875
$\frac{9}{64}$	.140625	$\frac{25}{64}$	.390625	$\frac{41}{64}$	.640625	$\frac{57}{64}$	.890625
$\frac{5}{32}$	.15625	$\frac{13}{32}$	.40625	$\frac{21}{32}$	.65625	$\frac{29}{32}$	.90625
$\frac{11}{64}$	.171875	$\frac{27}{64}$	.421875	$\frac{43}{64}$	.671875	$\frac{59}{64}$	.921875
$\frac{3}{16}$	.1875	$\frac{7}{16}$	.4375	$\frac{11}{16}$	.6875	$\frac{15}{16}$	.9375
$\frac{13}{64}$	.203125	$\frac{29}{64}$	.453125	$\frac{45}{64}$	.703125	$\frac{61}{64}$	.953125
$\frac{7}{32}$	.21875	$\frac{15}{32}$	.46875	$\frac{23}{32}$	.71875	$\frac{31}{32}$	.96875
$\frac{15}{64}$	.234375	$\frac{31}{64}$	.484375	$\frac{47}{64}$	.734375	$\frac{63}{64}$	.984375
$\frac{1}{4}$	.25	$\frac{1}{2}$	.5	$\frac{3}{4}$	.75	1	

ADVERTISEMENTS

ELEMENTS OF

MECHANICAL DRAWING

Use of Instruments, Geometrical Problems, and Projection

By GARDNER C. ANTHONY, Sc.D.

Professor of Drawing and Dean of the Engineering School, Tufts College
Member of the American Society of Mechanical Engineers

THIS is a text-book rather than a copy-book. It establishes principles and suggests methods, but permits freedom in their application.

The system of projection taught is that which the best practice demands, and examples have been selected with a view to establishing its principles with the least expenditure of time. The solution of geometric problems is required by practical methods in use by draftsmen, as well as by the ordinary geometric construction.

The methods employed for the representation of objects oblique to the planes of projection give a clear and comprehensive understanding of the subject.

The graphic statement of problems, which gives a definite lay-out, is a great labor-saving device for instructor and student.

Revised Edition.   *Cloth.*   *Illustrated.*   *160 pages, with 196 Illustrations and 228 Problems.*   *$1.50*

D. C. HEATH & CO., *Publishers*

BOSTON   NEW YORK   CHICAGO

MACHINE DRAWING

The Principles of Graphic Expression as illustrated by Machine Drawing, together with the Technique of Drafting, Dimensioning, and Sketching

By GARDNER C. ANTHONY, Sc.D.

Professor of Drawing and Dean of the Engineering School, Tufts College
Member of the American Society of Mechanical Engineers

THIS treatise is designed to serve as an advanced course in graphic expression for engineering students, and not solely, as its name might imply, as a course in machine drafting.

It is intended to teach exact methods of thought and clear expression in graphic language, to encourage the use of concise graphic terms by adopting the idiomatic phrases of the engineer, and to suggest useful means for acquiring facility in this form of expression.

Numerous problems have been chosen from practice with a view to obtaining the largest experience consistent with the minimum expenditure of time. These problems have received the severe test of use in the classes of evening schools, manual training high schools, and technical colleges.

Revised Edition. *Cloth.* *103 Pages of Text, Including 135 Illustrations and Useful Tables.* *$1.50*

D. C. HEATH & CO., *Publishers*

BOSTON   NEW YORK   CHICAGO

ESSENTIALS OF GEARING

By GARDNER C. ANTHONY, Sc.D.

Professor of Drawing and Dean of the Engineering School, Tufts College
Member of the American Society of Mechanical Engineers

THIS treatise comprises the course of instruction and problems given by Professor Anthony in college and evening drawing schools for several years past, and is the result of his practical experience in connection with designing and constructing gears.

Besides numerous cuts there are fifteen folding plates illustrating the principles and practice of describing gear teeth. A series of progressive problems is given, illustrating the principles set forth in the text, and also designed to encourage thorough investigation of the subjects by suggesting lines of thought and study beyond the limits of this book.

A definite lay-out for each problem is given, the necessary instruction for its solution is clearly stated, and numerous references to the text require the student to make a careful study of the subject before performing the problem. This enables a variety of original problems to be solved by a class with no additional labor on the part of the instructor.

Cloth. 84 pages of Text and 15 Folding Plates. $1.50

D. C. HEATH & CO., *Publishers*

BOSTON   NEW YORK   CHICAGO

DESCRIPTIVE GEOMETRY

DESIGNED FOR USE IN TECHNICAL SCHOOLS AND COLLEGES

By GARDNER C. ANTHONY, Sc.D.

Dean of the Engineering School and Professor of Drawing, Tufts College
Member of the American Society of Mechanical Engineers

And GEORGE F. ASHLEY

Assistant Professor of Drawing, Tufts College

IT has been the aim of the authors to present a clear and concise statement of the principles involved; to make a brief analysis and enumeration of the steps required in each problem, so that the essentials shall be clearly set forth; and finally to make a graphic statement of the problems to facilitate the lay-out and mechanical execution of the work.

The third angle of projection is largely used, but not to the exclusion of the other quadrants.

Although it is desirable to preface this study by a short course in instrumental drawing and the elements of orthographic projection, this treatise has been successfully studied by academic students who have not had such preparations.

Cloth.   *Illustrated.*   *130 Pages, with 195 Illustrations, 34 Plates, and 340 Problems.*   *$2.00*

D. C. HEATH & CO., *Publishers*

BOSTON   NEW YORK   CHICAGO

A TEXT–BOOK OF

FREEHAND LETTERING

By FRANK T. DANIELS, A.M.B.

Formerly Assistant Professor of Civil Engineering in Tufts College

THE plan of this book recognizes the fact that but little time can be given in technical schools to lettering as a special subject. Exercises are laid out and carefully planned, so that work may proceed rapidly.

Consideration is given to only the plain styles in common use by draftsmen. The methods suggested are wholly freehand, and are believed to be best calculated to lead to freedom of execution and excellence of result.

There is throughout an insistence that good lettering is a matter of design rather than the following of arbitrary rules. Copying is discouraged, and in many exercises is made impossible. Instead, there is ample exposition of the principles of design necessary to guide the student.

———————

Cloth.   78 pages, with 16 Plates and 12 Figures in the Text. $1.00

———————

D. C. HEATH & CO., *Publishers*

BOSTON   NEW YORK   CHICAGO